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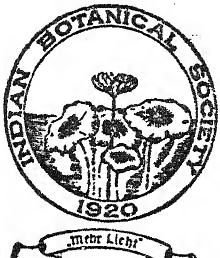
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CONTRIBUTIONS TO A SOUTH INDIAN MARINE ALGAL FLORA. I.

BY

F. Boergesen

Copenhagen

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Communicated by M. O. P. Iyengar

The following account of the marine algæ of South India is based mainly on collections made some years ago by Professor M. O. Parthasarathy Iyengar of Madras, who most kindly placed at my disposal all his collections of seaweeds with the exception of the Chlorophyceæ which he proposes to work out himself.

The collection consisted of a small number of dried specimens, consisting, as a rule, of only a single or sometimes a few specimens of each species, and a very large number of specimens preserved in 6% sea-water formalin. Since the material was kept in this solution for many years, sometimes even about as long as 20 years, the algæ were not always in their best condition.

In the beginning of 1928, I also made a small collection of algæ at Karvar in Bombay Presidency and at Tuticorin in South India during a short visit. Some species from these localities also are included in this account.

Of the larger algæ in the material examined by me, I did not find many forms of special interest; these have already been collected by HARVEY, FERGUSSON and others or have already been described in MME. WEBER's great work on the Siboga Algæ from the Malayan Archipelago. On the other hand, I came across many small epiphytes and endophytes which were often very interesting.

As in the following pages I shall often quote the papers of Indian algæ already published by myself, I give a list of them here with indications as to how they are cited. The papers are:—

Some Indian Rhodophyceae especially from the shores of the Presidency of Bombay, I-IV, in Kew Bulletin 1931, 1932, 1933, 1934; these papers will be quoted as "Kew Bull." 1931, 1932 and so on.

Some Indian green and brown algae especially from the shores of the Presidency of Bombay, I-III, in the Journal of the Indian Botanical Society, vol. IX, 1930, vol. XI, 1932 and vol. XII, 1933. These papers will be referred to as "Journ. Ind. Bot. Soc.", vol. IX, vol. XI and vol. XII.

Some marine algae from the Northern part of the Arabian Sea with Remarks on their geographical Distribution in Kgl. Danske Videnskabernes Selskab. Biologiske Meddelelser, XI, 6, Koebenhavn, 1934. This paper will be quoted as "Some mar. Alg. Arabian Sea."

A list of marine Algae from Bombay. ibid. XII, 2, Koebenhavn, 1935. This paper will, be quoted as "List mar. Alg. Bombay."

When Professor IYENGAR is the collector of a plant, I have in most cases used the abbreviation, M. O. P. I. When I myself have gathered the plant I have put ! after the name of the locality.

CHLOROPHYCEÆ

I. Ulotrichales.

Fam. 1. ***Chætophoraceae.***

Phaeophila Hauck.

1. **Phaeophila dendroides** (Cr.) Batters, Cat. Brit. Alg. 1902, page 13. HAMEL, Chlorophycèes des côtes françaises, 1930, page 27. *Ochlochæte dendroides* Crouan, Flor. Finist., page 128.

This species was found abundantly on old leaves of *Enhalus acoroides* gathered in October 1921 by M. O. P. IYENGAR. The creeping filaments were from 12-33μ thick.

India: Pamban, leg. M.O.P.I.

Distr.: Mediterranean Sea, Atlantic coast of Europe, Canary Islands, West Indies, etc.

II. Siphonocladiales.

Fam. 1. ***Valoniaceæ.***

Valonia Ginn.

1. Valonia Forbesii Harv. Alg. Ceylon. No. 75, (nomen nudum). J. AGARDH, Till Algernes Systematik, VIII, page 96. F. Boergesen, Some marine algae from Ceylon. Ceylon Journ. Sci. (A) Vol. XII, Pt. 2, 1936, p. 62, fig. 1.

I collected some very fine specimens of this species at Tuticorin. The specimens are mentioned and figured in a paper on some marine Algæ from Ceylon which will shortly be published in the Ceylon Journal of Science, Botany.

India: Tuticorin.

Distr.: South India, Malayan Archipelago, Tahity Friendly Islands, etc.

III. Siphonales.

Fam. 1. ***Codiaceæ.***

Codium Stackh.

1. Codium coronatum Setch., Tahitian Algæ in Univ. of Cal. Publ. in Bot., Vol. 12, 1926, p. 82, pl. 10, figs. 2-5; pl. 11, figs. 2, 3; pl. 12, figs 1, 5.

This characteristic species is easily recognised by its irregularly shaped, coxcomb-like thallus. It was originally described from Tahity and seems to be fairly well distributed in the Indian-Pacific Ocean.

India: Tuticorin: Hare Island.

Distr.: Tahity, Ceylon, India.

PHAEOPHYCEÆ

I. Ectocarpales.

Fam. 1. ***Ectocarpaceæ***

Ectocarpus Lyngb.

1. Ectocarpus Duchassaingianus Grun. Algæ, in Reise der Osterreichischen Fregatte Novara um die Erde, Bot. Theil, 1. Bd., 1870, p. 45, tab. IV, fig. 1. BOERGESEN, Mar. Alg. D.W.I., vol. I, pp. 159-162, figs. 127-8. SETCHELL, W. A., American Samoa (Department of Marine Biology of the Carnegie Institution of Washington, vol. XX, 1924, p. 170, fig. 35.)

The Indian specimens like those found by SETCHELL are much smaller than the West Indian ones forming low dense dark brown tufts about ½ cm. high on the old stems of other algæ; the small size of the Indian specimens is evidently due to its growing in an open, very much exposed surf-beaten locality. In size and shape, the plurilocular sporangia of the alga agree very well with those of the West Indian plant as well as with SETCHELL's figure quoted above, the only difference from the West Indian plant being that the sporangia in the Indian plant are a little less clavate or not clavate at all, often being thickest near the middle and agreeing with most of the sporangia in SETCHELL's figure. As pointed out by me, l. c., p. 160-1, and later by SETCHELL, p. 170, I think that the *Ectocarpus indicus* mentioned by MME. WEBER (Algues. .. Siboga, p. 130, fig. 34) is merely a form of *Ectocarpus Duchassaingianus*. I collected the plant during a visit to the Seven Pagodas in the month of February along with Prof. Iyengar.

India: Mahabalipuram (The Seven Pagodas)!

Distr.: West Indies, Tutuila Island, Malay Archipelago(?).

2. **Ectocarpus Mitchellae** Harv., Nereis Bor. Am. Part I, 1851, p. 142, pl. XXI, fig. G. BOERGESEN in Journ. of the Ind. Bot. Soc., vol. IX, 1930, p. 165, fig. 8 (here more literature and synonyms).

Intermingled among *Ectocarpus coniferus* in a collection of algæ from Pamban was found an *Ectocarpus* with cylindrical sporangia. The shape of the plurilocular sporangia in this plant agreed exactly with ASKENASY's figure in "Flora", 1894, pl. 1, fig. 6. Further, this plant was also very much like SETCHELL's figure in "American Samoa" (in Department of Marine Biology of the Carnegie Institution of Washington, vol. XX, 1924, pp. 169-170, fig. 34). SETCHELL considers his plant to be like *Ectocarpus indicus* Sonder, whereas ASKENASY presumes that *Ectocarpus indicus* has two forms, one the above mentioned form with cylindrical sporangia and another with conical sporangia (compare his figure l.c., pl. II, fig. 8*).

Referring the reader to my remarks in the paper quoted above, I feel inclined to consider the forms with cylindrical sporangia mentioned therein as belonging to HARVEY's *Ectocarpus Mitchellae*. Until now I have examined numerous specimens most probably belonging to this plant and from widely spread localities that it seems impossible to separate them. Since *Ectocarpus Mitchellae* is an older name (1851) than SONDER'S *Ectocarpus indicus* (1854), we are saved the difficulty regarding SONDER's species, the orginal specimen of which, as pointed out by SETCHELL, most probably consists of a mixture of several species.

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* I think that the last mentioned form with conical sporangia is like the plant I have described as a new species, *Ectocarpus coniger* Boergs., in "A List of Marine Algæ from Bombay" (Biologiske Meddelelser, XII, 2, Koebenhavn 1935, pp. 31-34, figs. 14-16).

India: Pamban, Oct. 1922, leg. M. O. P. I.

Distr.: Seems to occur in most warmer seas.

3. Ectocarpus coniferus Boergs.,[1] Mar. Alg. D.W.I., vol. I, 1914, p. 164, figs. 131-2.

When I found this plant (fig. 1), in Professor IYENGAR's collection, I was immediately struck by its great resemblance to the West Indian species, *Ectocarpus coniferus,* which is evident when one compares the accompanying figure with my figures quoted above. And, after a thorough comparison with the original material, I feel quite certain that the Indian plant cannot be separated from the West Indian one. The Indian specimens were found as epiphytes on old leaves of the sea-grass, *Enhalus acoroides*, to which the basal decumbent filaments were attached. The main filaments are about 40μ thick and are composed of cells of about the same length or up to 3-4 times the breadth; the branches become gradually thinner upwards. Near the base of the branches an intercalary zone of division is found from which the cells upwards become longer and thinner and gradually die away near the tip. In the zone of division the cells are crowded with chromatophores, which become more scattered upwards, the cells uppermost being almost colourless. The chromatophores have the shape of roundish discs. The plurilocular sporangia are placed in the way characteristic for this species, that is, singly or in short rows on the upper side of the branches near the base and especially in the corners. Two, three and sometimes more sporangia placed serially are found here. The plurilocular sporangia are oblong-conical with broadly rounded bases. They are always sessile and vary very much in size, being about 80-120μ long or more and about 30-40μ broad. I have not succeeded in finding any unilocular sporangia. It may be seen from this description that the Indian plant agrees in all respects with the West Indian one.

As I have already pointed out, its method of growth, shape of sporangia, etc., show some likeness to *Ectocarpus irregularis* Kütz., but nevertheless it differs from it, in many respects. This will be seen when one compares my figures with KUCKUCK's figure published in OLTMANNS' Morphologie und Biologie der Algen, vol. II, 1922, p. 9, fig. 294. *Ectocarpus coniferus* may perhaps also remind one somewhat of *Ectocarpus coniger* Boergs. in "A List of Marine Algæ from Bombay" (Biologiske Meddelelser, XII, 2, Koebenhavn 1935, p. 31, figs. 14-16). But, besides other differences, the sporangia in this species are often pedicellate and their shape varies very much.

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(1) See postscript on p. 7.

Ectocarpus coniferus, however, seems to be much more like *Ectocarpus arabicus* Figari and De Notaris described in Nuovi Materiali per l'Algologia del Mar Rosso (Memorie della Reale Academia delle Scienze di Torino, Ser. II, t. XIII, 1853, p. 169, fig. V), a paper which I have not seen until recently. Even if FIGARI and DE NOTARIS' figure is rather schematical, it must

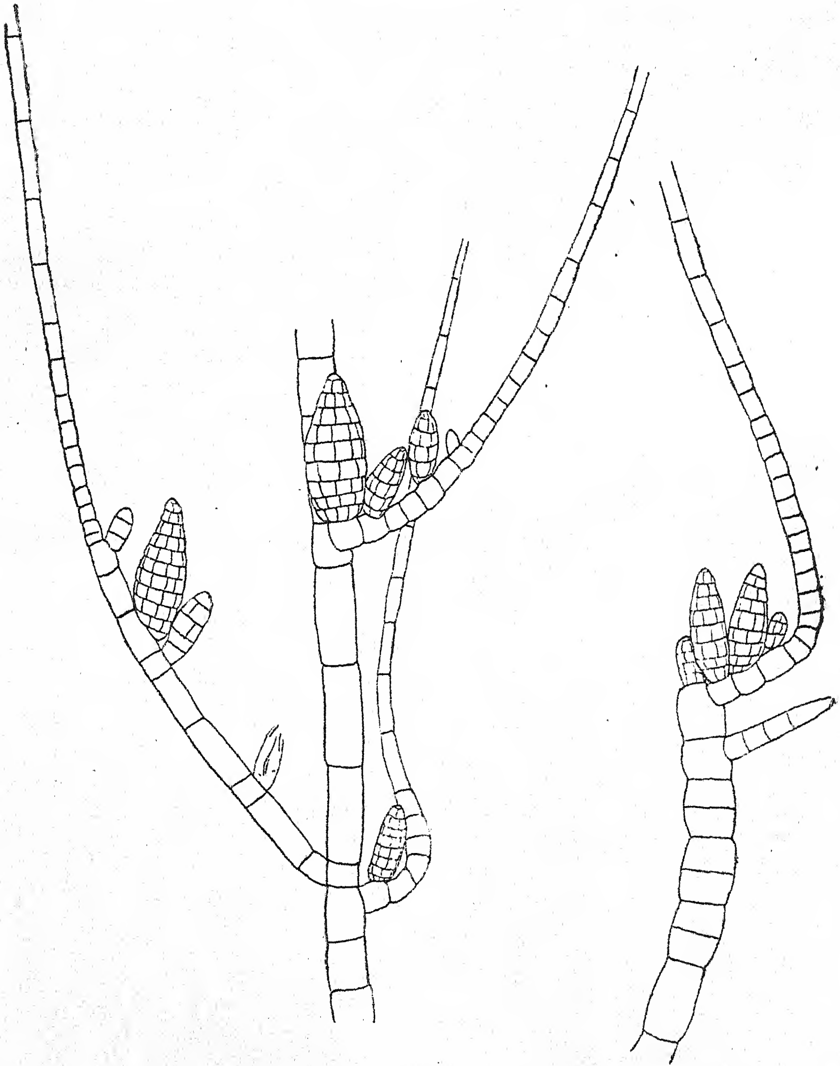


Fig. 1. *Ectocarpus coniferus* Boergs. Parts of filaments with plurilocular sporangia. × 250.

be admitted that the shape and position of the sporangia in the corners of the branches quite agree with those of my plant. Whether the sporangia, as is often the case with my species, also occur scattered along the upper side of the branches in the plant from the Red Sea neither FIGARI and DE NOTARIS' figure nor their description give any information about. To decide this point an examination of the original material is necessary and, until this is done, I think it is right that my species should be maintained. In this connection I wish to mention further that KÜTZING two years later in Tabulæ Phycologicæ, vol. V, tab. 72, has described an *Ectocarpus arabicus* nov. spec. which in the shape of its sporangia shows some likeness to this species, but in other respects is very different, for instance in the way in which the sporangia are placed, these being often pedicellate. And further it is quite a small plant forming tufts scarcely ½ cm. high. DE TONI (in Sylloge Alg., vol. III, Phæophyceæ, p. 546) refers KÜTZING'S plant to FIGARI and DE NOTARIS' species and, if DE TONI is right in doing so, my plant of course cannot be referred to FIGARI and DE NOTARIS' species.

The plant was gathered by IYENGAR in October 1921 as an epiphyte on *Enhalus acoroides*.

India: Pamban, leg. M. O. P. I.

Distr.: West Indies.

Postscript.—Long before I had thought it would be possible, I was able to examine some well preserved material of *Ectocarpus arabicus* Fig. et De Not. from the Red Sea. A young Egyptian algologist, Mr. A. H. NASR, from theUniversity of Cairo, has come to Copenhagen for some time in order to study a collection of marine algae gathered by him near the Egyptian Biological Station at Ghardaqa on the Red Sea. While looking through his collection of *Ectocarpus*, I came across some very good material of a plant which looked very much like FIGARI'S and DE NOTARIS' species, *Ectocarpus arabicus*. In this Red Sea material I find that the sporangia are placed not only in the corners of the branches as shown in FIGARI'S and DE NOTARIS' figures but also scattered all along the upper side of the branches. On the whole this plant resembles the Indian as well as the West Indian plants of *Ectocarpus coniferus*. The only difference I find is the sporangia in the plant from the Red Sea are somewhat shorter and proportionately thicker than those the West Indian plant, but this may perhaps be due to the fact that the plant from the Red Sea seems to be rather young, and the sporangia are not yet fully developed. The largest sporangium found by me in the material from the Red Sea is 92μ long and 38μ broad, white most of them were about 75μ long and 34μ broad only. But, leaving this minor difference out of consideration, the plant from the Red Sea agrees so well with the West Indian and the Indian plants that I do not hesitate in referring them all to the same species and calling them by FIGARI's and DE NOTARIS' name, *Ectocarpus arabicus*, as the older one and with *Ectocarpus coniferus* as a synonym.

Like *Ectocarpus Mitchellae* and *Ectocarpus Duchassaingianus*, (both these species are also found in Mr. NASR's collection), this species also seems to have a very extensive distribution in warm seas.

Botanical Museum, Copenhagen, Sept. 1936.

4. **Ectocarpus Enhali** nov. sp.

Thallus epiphyticus, minutus, pulvinaria parva ad 1 mm. alta formans, ex filamentis repentibus et filamentis erectis compositus. Filamenta repentia sinuosa, plus minus irregulariter ramosa, e cellulis ca. 15μ latis et 2-4 plo longis formata. Filamenta erecta simplicia, raro ramosa, divisione cellularum intercalari in parte inferiore filamentorum crescentia, e cellulis ca. 15μ latis et 1½-3 plo longioribus, superne attenuata e cellulis 5μ latis et 100μ longis et ultra composita.

Sporangia plurilocularia terminalia aut lateralia, sessilia, oblonga, ca. 40-60μ longa et 18-22μ lata.

India: Pamban, on old leaves of *Enhalus acoroides* leg. M. O. P. I.

On old leaves of *Enhalus acoroides* was found a small *Ectocarpus* (figs. 2, 3) with creeping basal filaments. The creeping filaments are branched now and then and irregularly bent; they are about 15μ thick and composed of cells about two to four times as long. From the creeping filaments, the erect ones arise. These are of variable length, the longer ones reaching a height of about 1 mm. or more. The filaments are composed of cylindrical cells about 11-15μ broad and are shortest near the base, about 1½-3 times as long as broad becoming gradually longer upwards, being in the upper ends often more than 100μ long and tapering gradually to about 5-8μ. At the cross-walls the filaments are a little constricted. The upper cells in the younger filaments have a broadly rounded apex; in older filaments the uppermost cells die gradually. No marked growing point is found, but the cells in the lower parts of the filaments are divided occasionally. The chromatophores seem to consist of irregularly elongated or rounded discs, but as they have been kept in formalin for a long time they are rather damaged. The erect filaments are generally unbranched; only now and then does a filament send out a single branch.

The plurilocular sporangia are placed either terminally on short erect filaments or laterally on the long filaments. As far as I have seen they are always sessile. They are oval-oblong in shape with broadly rounded apices and bases about 40-70μ long and about 22-28μ broad.

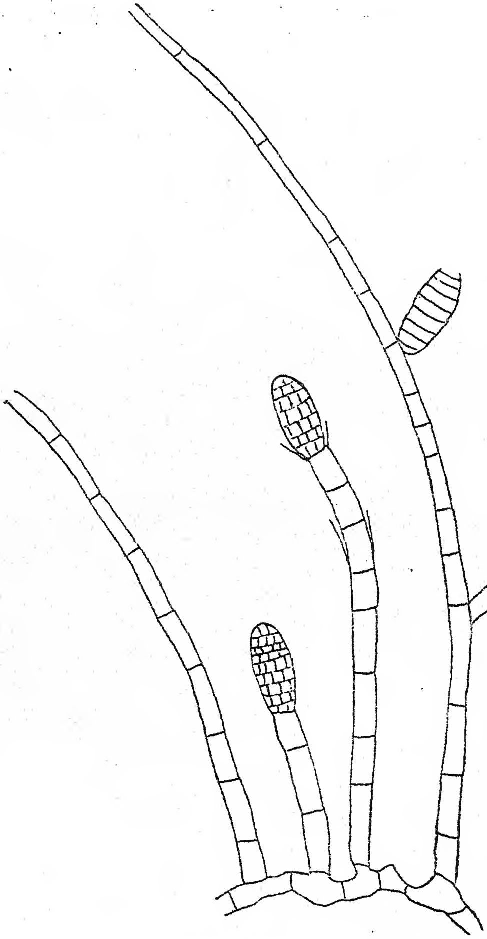


Fig. 2. *Ectocarpus Enhali* nov. sp. Part of the thallus with plurilocular sporangia. About × 300.

This species is probably related to *Ectocarpus Laurenciæ* Yamada (Notes on some Japanese Algæ II in Journ. Hokhaido Imp. University, Series V, vol. I, 1931, p. 66, fig. 1) but the Japanese plant differs in having apical growth. It may also remind one somewhat of *Ectocarpus columellaris* Boergs from Galle, Ceylon, (F. Boergesen, Some marine algae from Ceylon. Ceylon Journ. Sci. (A) Vol. XII, Pt. 2, 1936, p. 72, fig. 4). but this species is altogether smaller and the sporangia occasionally pedicellate. It must also be compared with the plant, which I have referred in Mar. Alg. of the Danish West Indies, vol. II, p. 434, fig. 410, though with some doubt, to *Ectocarpus variabilis* Vickers, and which, like this plant, grows on old leaves of a sea-grass, but the West Indian plant is smaller and the sporangia are not only sessile but also pedicellate.

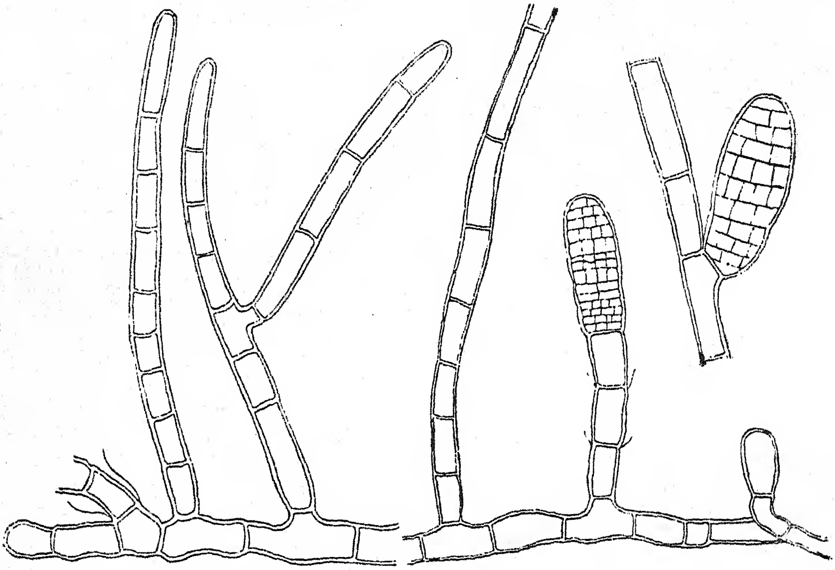


Fig. 3. *Ectocarpus Enhali* nov. sp. Parts of plants with plurilocular sporangia. × 500.

5. **Ectocarpus filifer** nov. sp.

Thallus in *Liagora erecta* subepiphyticus, cæspites parvos ad 1 mm. altos formans, e filamentis repentibus, parce ramosis, et filamentis erectis compositus. Filamenta repentia plus minus inter filamenta assimilatoricis hospitis immersa, irregulariter sinuosa e cellulis ca 7-10μ latis et 4-5 plo longioribus formata. Filamenta erecta, divisione intercalare in parte basale filamentorum crescentia, fere cylindrica ad septa transversaria leviter constricta e cellulis ca. 10-12μ latis et 2-4 plo longioribus constructa. Sporangia plurilocularia terminalia in pedicellis brevibus ex filamentis repentibus ortis, aut in parte basale filamentorum erectorum sessilia vel pedicellata, cylindrice-pyriformia, ca. 60-90μ longa et 22-27μ lata.

India: Mahabalipurum (The Seven Pagodas), leg. M. O. P. I.

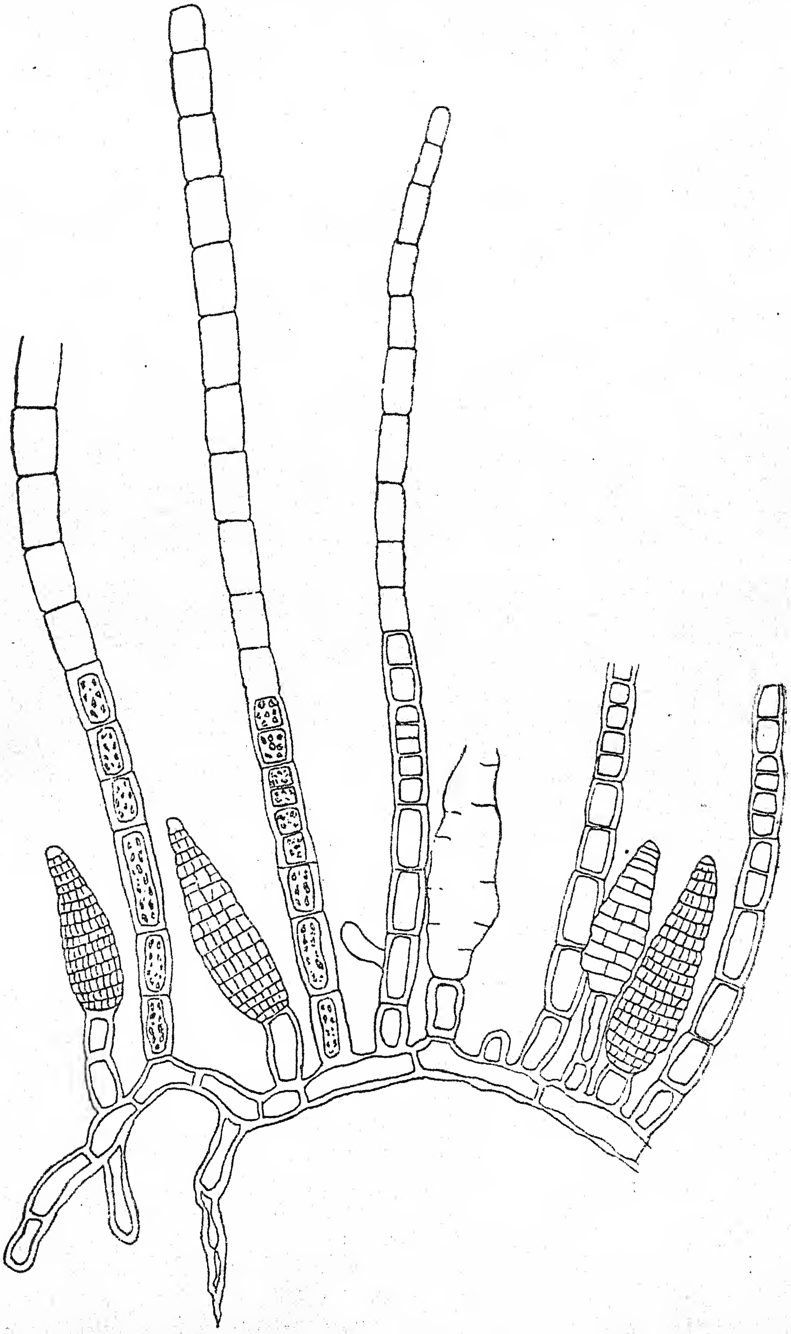


Fig. 4. *Ectocarpus filifer* nov. sp. Part of the thallus with plurilocular sporangia. About × 400.

This plant (figs. 4, 5) forms low felted cushions up to about 1 mm. high on *Liagora erecta*. The thallus consists of creeping filaments more or less immersed among the assimilating filaments of the host and from which erect filaments arise. The creeping filaments are irregularly ramified and sinuated, about 7-10μ thick and composed of shorter or longer cells from a little longer than broad up to about 4-5 times as long. From the upper sides of the creeping filaments are formed long assimilating shoots as well as short ones composed merely of a single or a few cells, the latter ending in plurilocular sporangia. The assimilating filaments have an intercalary short zone of division a little above the base. They have rather thick walls and are a little constricted at the cross walls. They are composed of cells about 10-12μ broad and 2-4 times as long and tapering more or less upwards. The apical cells are broadly rounded at the top. The cells contain several small irregularly shaped or roundish disc-shaped chromatophores. As far as I have been able to see, the erect filaments are not branched. The plurilocular sporangia are placed terminally on the short one- or two-celled filaments given out from the creeping filaments. They are elongated-pyriform to conical in shape and about 60-90μ long and 22-27μ broad. Moreover, sporangia are found now and then on the branches issuing from the lower part of these. These sporangia have almost the same shape but are generally smaller. They are pedicellate or sessile.

This species may remind one somewhat of *Ectocarpus Enhali* Boergs. described in this paper, of *Ectocarpus columellaris* Boergs. (from Galle, Ceylon) and of *Ectocarpus Laurenciæ* Yamada, but it differs from these in several respects.

6. **Ectocarpus thyrsoideus** nov. sp.

Thallus cæspites parvos ad 3-4 mm. altos formans, ex filamentis endophyticis valde ramosis et irregulariter sinuosis inter filamentis hospitis *(Liagora erecta)* circumvagantibus et ex filamentis erectis liberis sporangiferis compositus. Filamenta endophytica ex cellulis ca. 22μ latis et 2-5 plo longioribus formata. Filamenta erecta, sparse ramosa, divisione intercalari crescentia, ex cellulis plus minus doliiformibus ad septa transversaria constrictis ca 18-25μ latis et 1-6 plo et ultra longioribus constrüctis, Chromatophora irregulariter bacilliformia aut rotundata. Sporangia plurilocularia oblique cylindrico-conica, sessilia aut pedicellata, ca. 140μ longa et 25-35μ lata in filamentis erectis adsunt.

India: Mahabalipuram, Jan. 1922, leg. M. O. P. I.

This plant (figs. 6, 7) forms dense felted tufts about 3-4 mm. high. It consists of a basal part of very much and irregularly ramified filaments and an upper part of long and more or less ramified filaments bearing the plurilocular

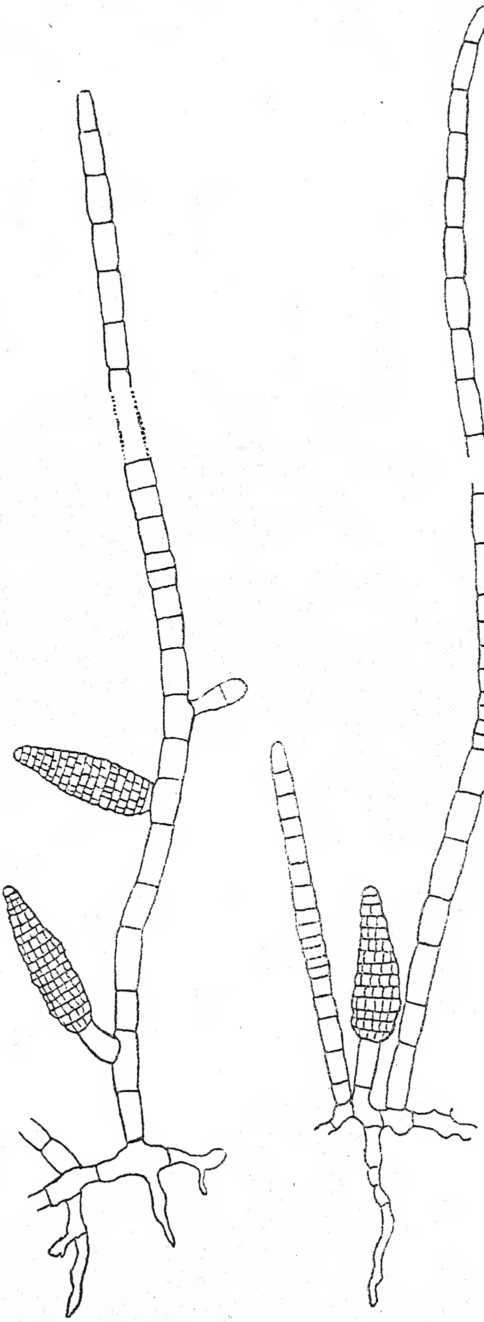


Fig. 5. *Ectocarpus filifer* nov. sp. Parts of the thallus with unilocular sporangia. × 250.

sporangia. The decumbent filaments are composed of very irregularly shaped cells, about 22μ broad and 2-5 times as long and are very much ramified, sending out branches in all directions between the filaments of the host. Some of the branches become rhizoid-like and grow more or less inwards into the tissue

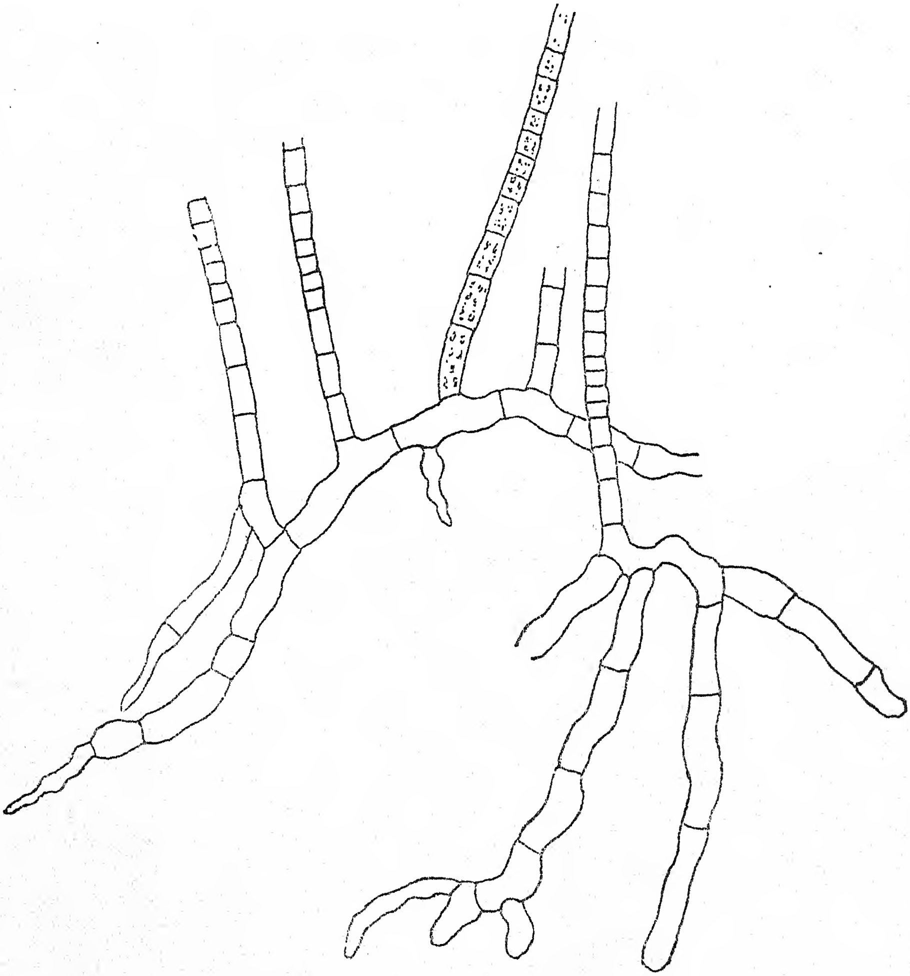


Fig. 6. *Ectocarpus thyrsoideus* Boergs. Basal parts of the plant. × 300.

of the host. From this large and complicated basal part the erect filaments are given out. They are composed of almost cylindrical cells somewhat constricted at the cross-walls about 18-25μ

thick and 1-6 times or more long. A zone of division is found somewhat above the base of the filaments in the young filaments, in the older ones it moves upwards to about the middle of the filaments and often becomes very long; above it the cells become slowly longer and longer and more and more destitute of

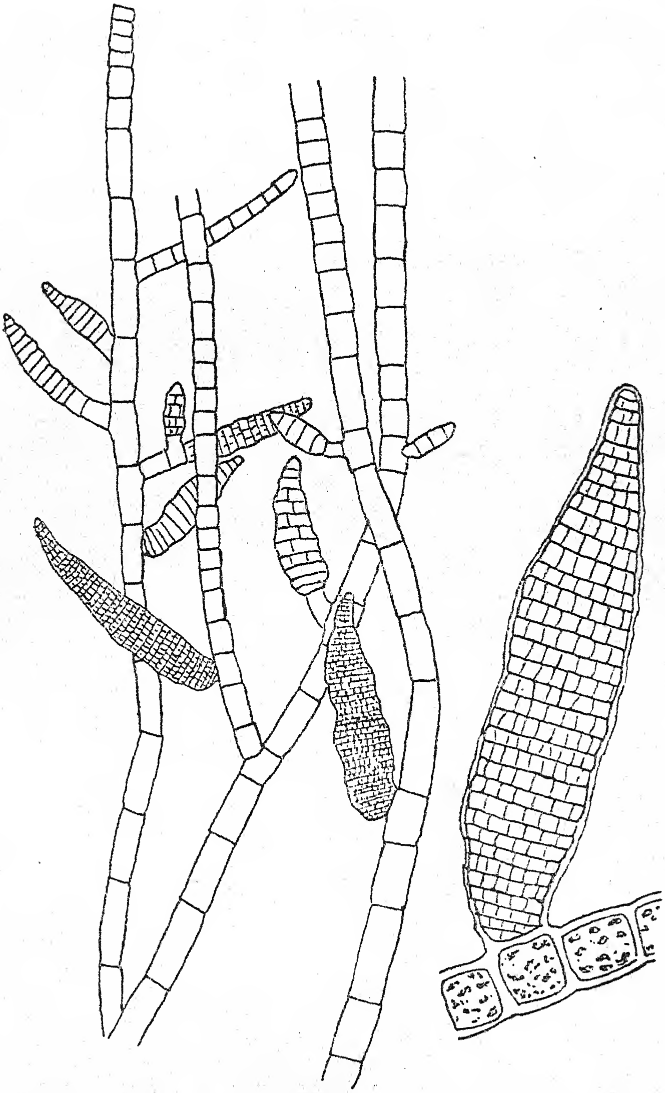


Fig. 7. *Ectocarpus thyrsoideus* Boergs. Filaments with plurilocular sporangia. × 300 and × 500.

chromatophores, and then die gradually in the upper ends of the filaments. The chromatophores are disc-shaped, irregularly strap-shaped or roundish.

Most of the filaments are unbranched ; only a few become branched and form single or a few branches.

The plurilocular sporangia are found scattered on the filaments. They are generally sessile, but occasionally pedicellate. They are more or less obliquely elongated, conical and irregularly constricted or sinuate up to about 140μ long and 25-35μ broad.

Since it resembled in several respects *Ectocarpus filifer* with which it was growing, I was at first not quite sure if they were not one and the same plant, but I have come to the conclusion that they must be kept apart. *Ectocarpus filifer* is a smaller plant which generally has terminally placed sporangia, which are not found in *Ectocarpus thyrsoideus*, and the sporangia placed on the assimilating filaments were more rare, whereas they were found only on the assimilating filaments in *Ectocarpus thyrsoideus*. An examination of the living material will certainly decide this question.

7. **Ectocarpus geminifructus** nov. sp.

Thallus ad 250μ altus ex filamentis endophyticis irregulariter ramosis, in thallo hospitis (*Liagora erecta*) repentibus, et filamentis erectis assimilatoriis, pilis et sporangiis libere emergentibus compositus. Fila endophytica inter filamenta assimilatoria hospitis circumvagabunda, ca. 7-12μ lata ex cellulis usque duplo longioribus sæpe longitudinaliter divisis formata. Filamenta erecta ad 250μ alta divisione intercalare crescentia superne aut obtusa aut pilifera., ca. 9-11μ lata, ex cellulis longitudinis eiusdem aut plus minus longioribus, sæpe longitudinaliter divisis, et chromatophora 3-6 disciformia continentibus. Pili ca. 8-9μ lati. Sporangia plurilocularia saccata, superne late rotundata, ca. 70μ longa et 27μ lata, in apicibus filamentorum brevium procrescentia, sæpe geminata extant.

India: Mahabalipuram (The Seven Pagodas) in *Liagora erecta*, leg. M. O. P. I.

The basal part of this interesting *Ectocarpus* (figs. 9, 10) is endophytic and composed of irregularly bent ramified filaments creeping round in the slimy calcified mass surrounding the assimilating filaments of the host. From this basal part the assimilating shoots, hairs and sporangia issue above the surface of the host. Especially characteristic of this species are the numerous longitudinal walls found not only in the endophytic

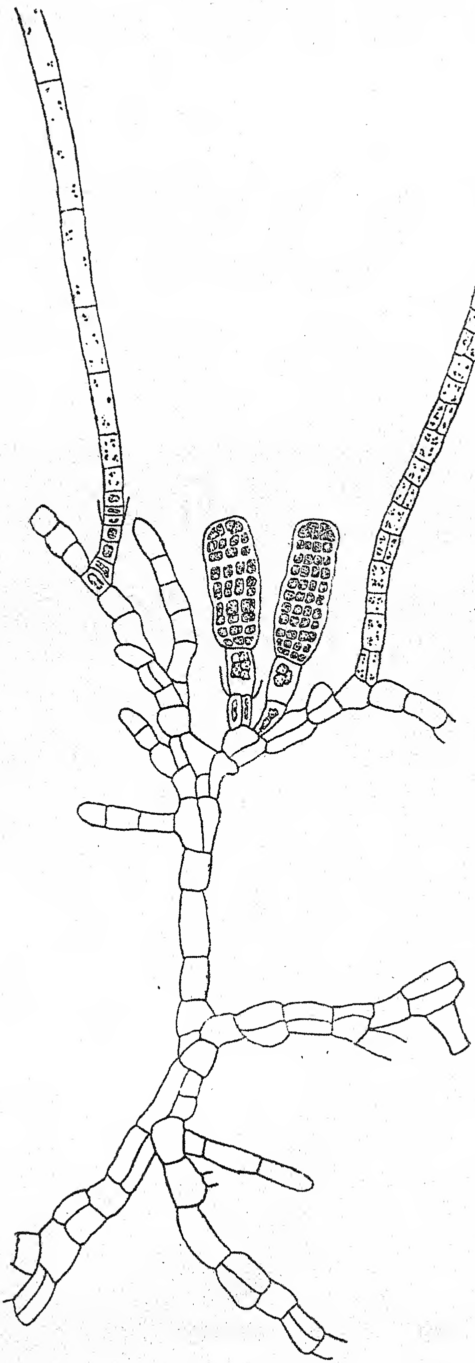


Fig. 8. *Ectocarpus geminifructus* nov. sp. Part of the thallus with plurilocular sporangia, assimilating filament and a hair. × 375.

filaments but also in the erect assimilating ones. And another characteristic feature is that the plurilocular sporangia often occur in pairs.

The creeping endophytic filaments are about 7-12µ thick and are composed of a row of cells nearly half of which are often divided by longitudinal walls into two cells. From this base the assimilating shoots, the hairs and the sporangia arise. The assimilating shoots vary in length, and are about 250µ long and often end in a hair, at the base of which a sheath is present. The assimilating shoots are about 9-11µ broad and the cells of which they are composed are as long as broad, the cells being often divided by longitudinal walls. The hairs which issue from the creeping filaments have a sheath at their base above which the zone of division is found. They are about 8-9µ thick.

The plurilocular sporangia are cylindrical-saccate in shape with broadly rounded apices and bases and are about 70µ long and 27µ broad. They are terminally placed on a more or less short filament which sometimes consists of a single cell only. When two sporangia are found together, the cells in the upper end of the filaments are divided by longitudinal walls, and at the top these cells are separate, each carrying a sporangium, reminding one of what sometimes takes place in *Ectocarpus terminalis* (compare my figures 27b, c, and 28a in Mar. Alg. from the Canary Islands, Part II, Phæophyceæ in Biol. Meddelelser, VI, 2, Koebenhavn, 1926, pp. 53-55.)

The many peculiar longitudinally divided cells of this species reminds one of *Streblonema patagonicum* Skottsberg (Botanische Ergebnisse der Schwed, Exped. nach Patagonien in K. Svenska Vetenskapsakademiens Handlingar, Bd. 61, No. 11, Stockh. 1921, p. 11, fig. 5), but otherwise there are many differences, e.g., the presence of assimilating filaments above the surface of the host in the Indian plant, the shape of the sporangia, etc. Compare also the following species.

8. **Ectocarpus Dermonematis** nov. sp.

Thallus endophyticus ex filamentis decumbentibus irregulariter ramosis in thallo hospitis (*Dermonema gracile*) repentibus et ex filamentis erectis brevibus assimilatoriis, pilis et sporangiis compositus.

Filamenta endophytica ca. 5-8-10µ lata ex cellulis 2-3 plo longioribus interdum longitudinaliter divisis formata. Filamenta assimilationis brevia ad 100µ alta, superne obtusa aut raro pilifera, ex cellulis ca. 8µ lata et longa, interdum longitudinaliter divisis et chromatophora 3-5 rotundata continentibus composita.

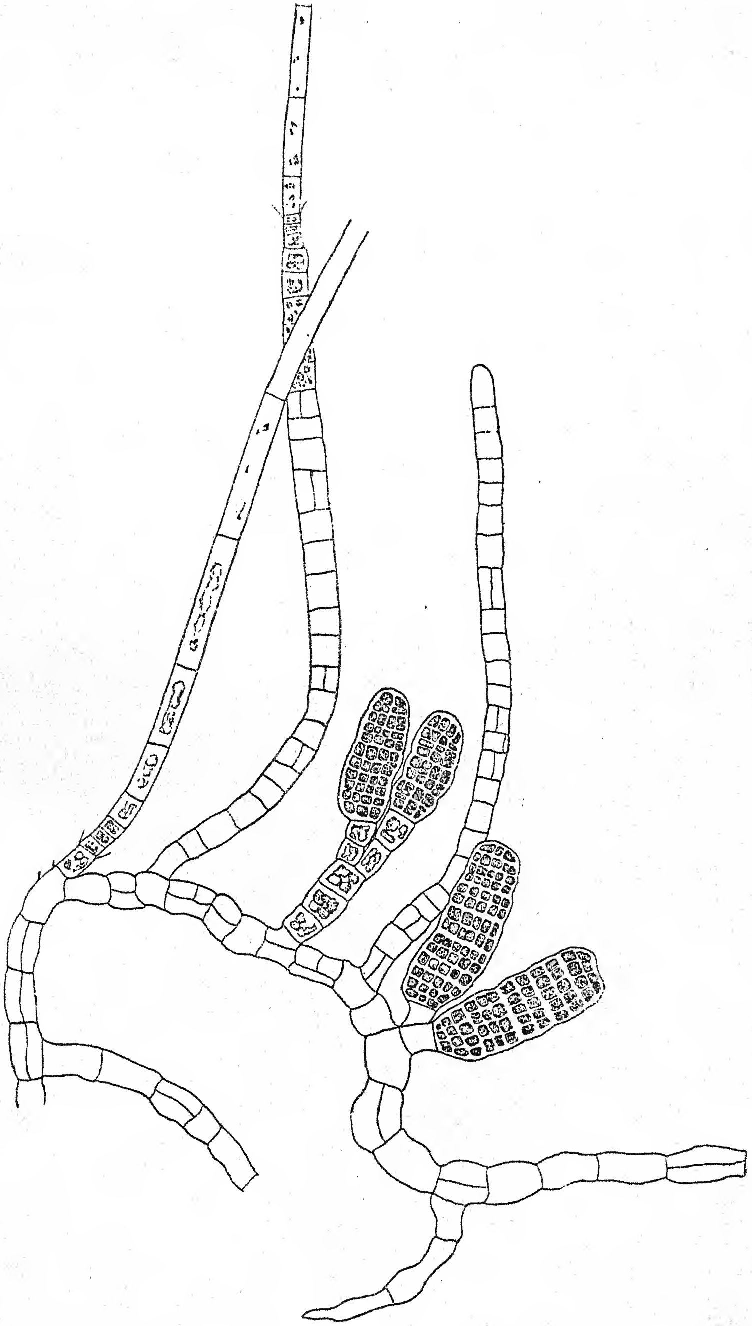


Fig. 9. *Ectocarpus geminifructus* nov. sp. Part of the thallus with plurilocular sporangia, assimilating filaments, one of which with a terminal hair and another hair. × 530.

Pili non numerosi, ca. 5μ lati. Sporangia plurilocularia late-ovalia-saccata, ca. 23-42μ longa et 13-17μ lata adsunt.

India: Cape Comorin, Oct. 1924, leg. M. O. P. I.

In the thallus of *Dermonema gracile* a small endophytic *Ectocarpus* (figs. 10, 11) was found the filaments of which were growing in between the assimilating filaments of the host and sending up short assimilating shoots, hairs and plurilocular sporangia. The plant appears to be nearly quite immersed in the tough mucilage of the host.

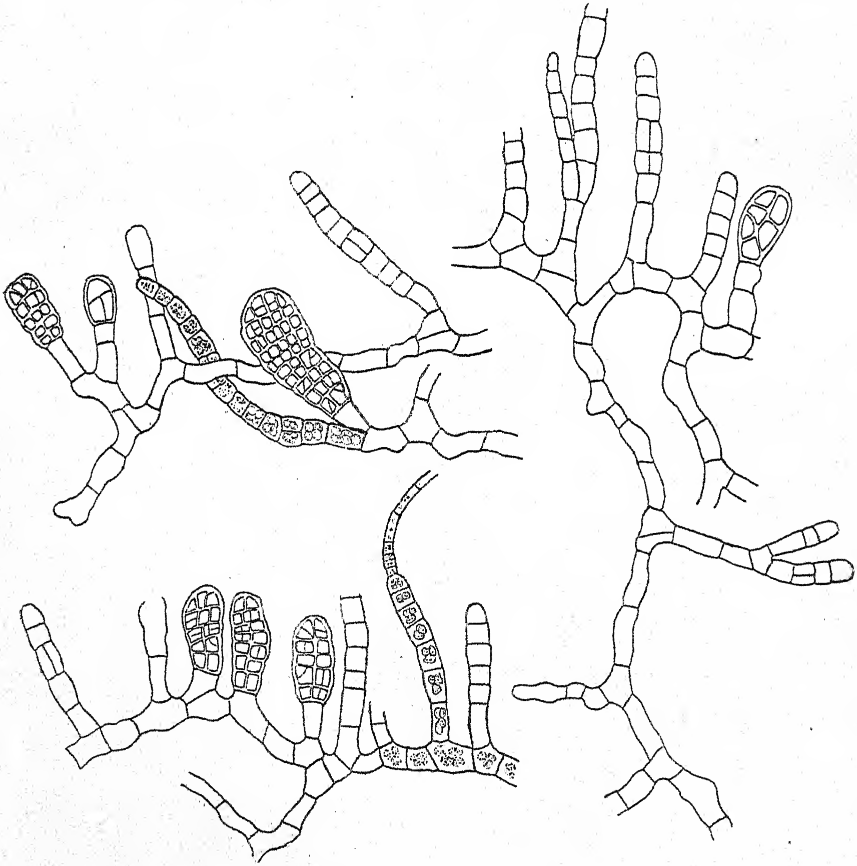


Fig. 10. *Ectocarpus Dermonematis* nov. sp. Parts of the plant with plurilocular sporangia and assimilating filaments, one with a terminal hair. × 450.

The creeping filaments are irregularly bent and sinuate and the cells also have more or less sinuate walls. The branching is quite irregular. The filaments in the thinner parts are about 5μ thick and in the thickest up to about 8-10μ; the length of the cells varies very much from as long as broad to 2-3 rarely

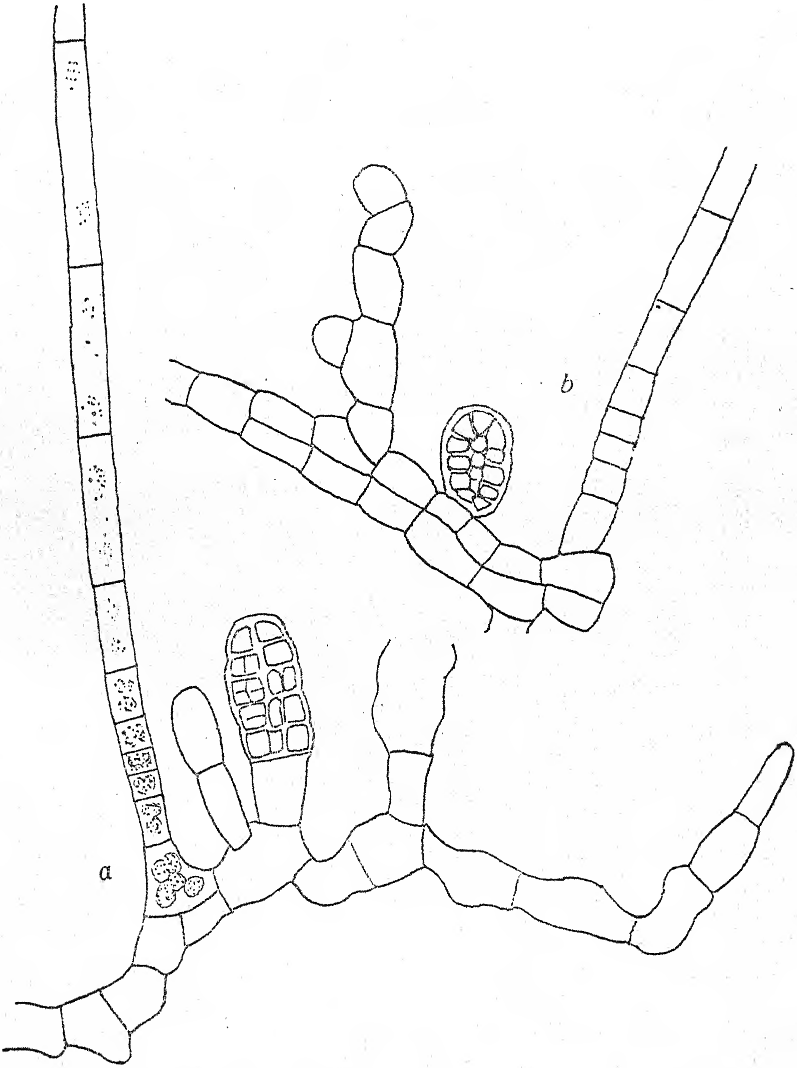


Fig. 11. *Ectocarpus Dermonematis* nov. sp. *a*, part of a plant with a plurilocular sporangium and a hair. *b*, part of an older plant with more longitudinally divided cells. × 800.

4 times as long as broad. The transverse walls are often more or less oblique; now and then when a sporangium or an assimilating filament grows out, the cells are divided by longitudinal walls into two cells. In old parts of the thallus, longitudinal walls are often rather common. The assimilating filaments are about 50-75μ or, very rarely, up to 100μ long or slightly longer and about 8μ broad; they are composed of rather short cells about as long as broad; now and then one of the cells is divided by a longitudinal wall. Most of the filaments end in a broadly rounded cell and sometimes though not often in a hair. The cells contain 3-5 roundish chromatophores. The hairs are not numerous; they have a zone of division near the base above which the cells gradually grow longer and colourless.

The plurilocular sporangia are broadly oval to saccate in shape, the smaller ones about 13μ broad and 23μ long, the larger about 42μ long and 17μ broad.

In many respects this species reminds one very much of *Ectocarpus geminifructus* described above. It grows in a similar way and has longitudinal walls and the shape of the sporangia shows much likeness. But it is smaller, and the sporangia are placed singly, though now and then a tendency to bifurcation is present. Because this plant seems to be nearly or quite immersed in the host, it ought perhaps have been referred to the genus *Streblonema*, but, since it is so very much like the preceding species, I keep it in the genus *Ectocarpus*. At any rate, these two species show that the limits of *Streblonema* from *Ectocarpus* are rather vague.

Streblonema Derb. et Sol.

1. **Streblonema turmale** nov. sp.

Thallus cæspites densos ca. 300-400μ altos formans. Filamenta decumbentia, endophytica inter filamenta hospitis (*Liagora erecta*) repentia, sparse ramosa, e cellulis irregulariter formatis ca.5-8μ latis et 1-3 et ultra longis composita. E filamentis decumbentibus periphericis sporangia plurilocularia, pili in superiore parte hyalini et filamenta assimilatoria oriuntur. Sporangia plurilocularia cylindrice-fusiformia, ca. 60μ longa et 4-8μ lata. Pili ca. ad 300μ et ultra longi et 4μ lati.

India: Mahabalipuram (The Seven Pagodas), leg. M. O. P. I.

On the old parts of the thallus of *Liagora erecta* Zeh a small *Streblonema* (figs. 12, 13) occurred forming low dense tufts near the surface of the host above which the colourless hairs protrude. The endophytic irregularly ramified filaments are creeping round about the assimilators of the host. They are composed of irregularly shaped cells about 5-8μ broad and 1-3 times as long. From the filaments approaching the surface of the host, sporangia, hairs and assimilating filaments issue. The plurilocular sporangia are pedicellate or rarely sessile ; they are placed either singly one on each cell or sometimes are crowded together on short branch-systems in corymbiform manner. The sporangia are cylindrical-spindle-shaped, about 60μ long and 4-8μ broad. In the middle where they are broadest they are divided more or less by oblique walls. The hairs are about 4μ thick and 300μ long and have a growing zone near their base dying away upwards. The assimilating filaments are nearly cylindrical and may sooner or later be transformed into sporangia. The cells contain two to three small irregularly shaped roundish disc-shaped chromatophores.

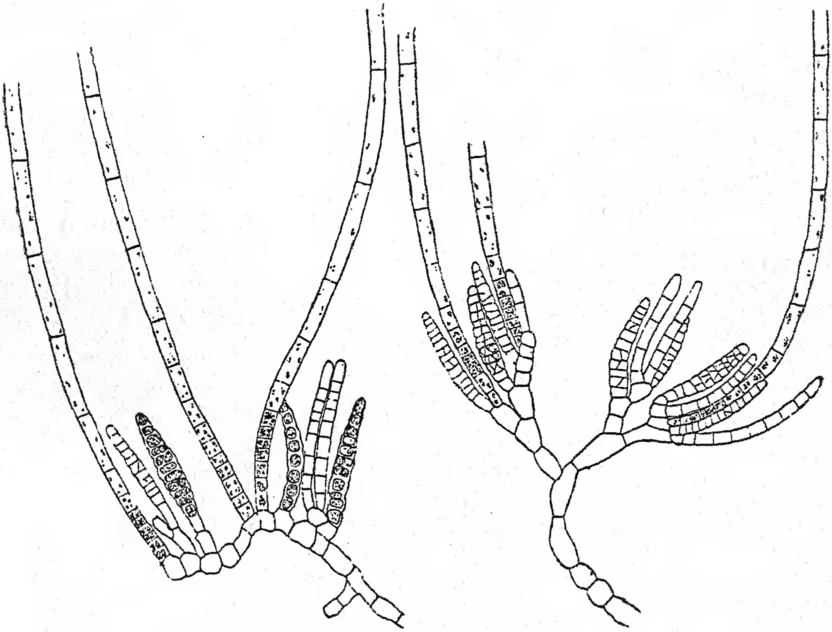


Fig. 12. *Streblonema turmale* nov. sp. Parts of the plants with plurilocular sporangia and hairs. × 400.

This little plant may remind one of *Streblonema corymbiforme* Setchell and Gardner in Phycological Contributions II-VI (University of California, Publications in Bot., vol. 7, 1922, p. 391) but in this species the sporangia have uniseriated loculi and hairs are absent. It is also closely related to *Streblonema tenuissimum* Hauck, Meeresalgen, p. 323, but this has only one row of loculi in the sporangia.

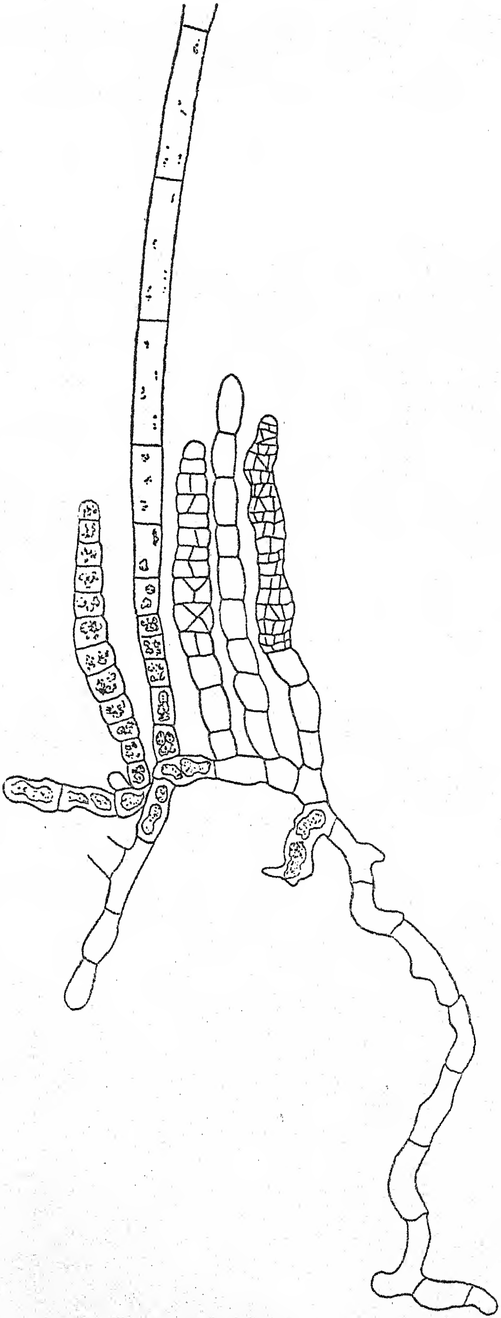


Fig. 13. *Streblonema turmale* nov. sp. Part of a plant with plurilocular sporangia and a hair. × 800.

Fam. 2. **Mesogloeaceæ.**

Sub-Fam. 1. **Myriogloceæ**

Myriogloea Kuck.

1. Myriogloea sciurus (Harv.) Kuck., Fragmente einer Monographie der Phaeosporeen, p. 62, fig. 81. BOERGESEN, in Journ. Ind. Bot. Soc., vol. XI, 1932, p. 63, fig. 6.

Since my paper quoted above was published, Miss PARKE has given a detailed description of this plant partly from the material sent to her by me. Compare her paper : A contribution to the knowledge of the Mesogloiaceæ and associated families (Publications of the Hartley Botanical Laboratories No. 9, Liverpool 1933). Whereas my material contained only plurilocular sporangia, Miss PARKE has found unilocular sporangia also in the material from South Africa.

The specimens now examined from South India likewise had only plurilocular sporangia. The specimens were gathered in October.

India: Cape Comorin, leg. M. O. P. I.

Distr.: India, Australia (N. S. Wales), Cape.

Fam. 3. **Scytosiphonaceæ.**

Rosenvingea Boergs.

1. Rosenvingea intricata (J. Ag.) Boergs. Cfr. BOERGESEN in Journ. Ind. Bot. Soc., vol. IX, 1930, p. 167.

The specimens form spongy masses.

India: Tuticorin: Hare Island,!

Distr.: Vera Cruz, Samoa, Australia, West Indies, etc.

2. Rosenvingea orientalis (J. Ag.) Boergs. Cfr. BOERGESEN, l.c., p. 168.

The shape of the specimens varies very much.

India: Tuticorin, Oct. 1923, leg. M. O. P. I.

Distr.: Indian Ocean, Formosa.

Fam. 4. **Encoeliaceæ.**

Hydroclathrus Bory.

1. Hydroclathrus clathratus (Bory) M. A. Howe in BRITTON and MILLSPAUGH, The Bahama Flora, New York, 1920, p. 590.

India: Tuticorin,! Shingly Island, leg. M. O. P. I.; Cave Matres, leg. M. O. P. I.

Distr.: Most tropical seas.

II. Sphacelariales.

Fam. 1. ***Sphacelariaceæ.***

Sphacelaria Lyngb.

1. Sphacelaria furcigera Kütz. Tab. Phycolog., vol. V, p. 27, pl. 90, fig. II. SAUVAGEAU, Remarques sur les Sphacélariacées, p. 145. (Journal de Botanique, vol. XV, 1901).

Several tufts with propagula were found on old stems of *Turbinaria*.

India: Krusadi Island, Oct. 1925, leg. M. O. P. I.

Distr.: Widely spread in temperate and warm seas.

III. Dictyotales.

Fam. 1. ***Dictyotaceæ.***

Stoechospermum Kütz.

1. Stoechospermum marginatum (Ag.) Kütz. Cfr. BOERGESEN in Journ. Ind. Bot. Soc., vol. XI, 1932, p. 67, fig. 8.

Most of the specimens gathered at the end of February were sterile; a single specimen from the beginning of March and another one from the middle of this month were fruiting.

India: Malvan, S. C. DIXIT; Karvar!; Tuticorin!

Distr.: India, Red Sea, Çeylon.

Padina Adans.

1. Padina tetrastromatica Hauck. Cfr. BOERGESEN in Journ. Ind. Bot. Soc., vol. IX, 1930, p. 172.

India: Cape Comorin, leg. M. O. P. I.

Distr.: Somaliland, India, Malayan Archipelago.

Dictyopteris Lamx.

1. D. delicatula Lamx. in Journ. Philom. 1809, No. 20, tab. 6, fig. B. cfr. BOERGESEN, Mar. Alg. D.W.I., vol. I, 1913-14, p. 216, figs. 166-7, where more literature is quoted.

At Tuticorin only sterile plants were found. The dredging was done in 2-3 fathoms of water.

India: Tuticorin, Hare Island!; Cape Comorin, leg. M. O. P. I.

Distr.: West Indies, Mexico, Brazil, Malayan Archipelago, etc.

Dictyota Lamx.

1. Dictyota Bartayresiana Lamx. Cfr. BOERGESEN, Mar. Alg. Arab. Sea, p. 29.

A specimen in IYENGAR'S collection is a female one, having the oogonia spread over the thallus.

India: Krusadi Island, Pamban, May 1924, leg. M. O. P. I.

Distr.: West Indies, Indian Ocean, Australia.

2. Dictyota dichotoma (Huds.) Lamx. forma *implexa* (Lamour.) J. Ag. *Dictyota implexa* Lamour., Essai . . . Thalassiophytes, 1813, p. 58. DELILE, Flore d'Egypte, p. 149, pl. 56, fig. 5.

The specimens found resemble DELILE'S figure. They are fruiting. The fructiferous organs are found in the middle of the thallus leaving a narrow sterile margin on both sides of it.

India: Tuticorin: Hare Island, leg. M. O. P. I.

Distr.: Mediterranean Sea, Atlantic Ocean, West Indies, Red Sea, etc.

3. Dictyota atomaria Hauck. Cfr. BOERGESEN in Journ. Ind. Bot. Soc., vol. XI, 1932, p. 69, figs. 9-10, pl. 2.

An old specimen and a young one are found. The specimens agree very well with some small specimens from Bombay.

India: Tuticorin,!.

Distr.: Bombay.

IV. Fucales.

Fam. 1. ***Fucaceae***

Cystophyllum J. Ag.

1. Cystophyllum muricatum (Turn.) J. Ag. Cfr. BOERGESEN, Mar. Alg. Arab. Sea, p. 29.

The specimens found belong to the typical form.

India: Tuticorin, Hare Island!. Pamban, Krusadi Island, Oct. 1916 and Oct. 1924, leg. M. O. P. I.

Distr. India, Malayan Archipelago, Australia.

RHODOPHYCEÆ

A. Protoflorideæ.

I. Bangiales.

Fam. 1. ***Bangiaceæ.***

Erythrotrichia Aresch.

1. **Erythrotrichia carnea** J. Ag. Cfr. BOERGESEN in Kew Bulletin, 1932, p. 113.

It was found on *Spathoglossum asperum.*

India: Tuticorin, February 1921, leg. M.O.P.I.

Distr. Atlantic Ocean, Mediterranean Sea, Indian Ocean, Pacific coast of America, etc.

B. Florideæ.

I. Nemalionales.

Fam. 1. ***Chantransiaceæ.***

Acrochaetium Nägl.

As is well known, the two genera *Acrochaetium* and *Rhodochorton* seem to be closely related and censequently have been united by some investigators, and the numerous species of *Acrochaetium* have been referred to *Rhodochorton.* Concerning this question, see especially KATHLEEN M. DREW, "A revision of the genera *Chantransia, Rhodochorton* and *Acrochaetium,* with descriptions of the marine species of *Rhodochorton* (Naeg.) gen. emend, on the Pacific coast of North America" (University of California Publications in Botony, vol. 14, No. 5, 1928) and *Rosenvinge, L. Kolderup,* "Distribution of the Rhodophyceæ in Danish Waters" (D. Kgl. Danske Vidensk. Selsk. Skrifter, Naturv. og math. Afd., 9, Række VI 2, Koebenhavn 1935). As all problems concerning this intricate question have not yet been solved, I prefer to maintain the genus *Acrochaetium.*

As pointed out by BORNET in his valuable paper, "Deux *Chantransia corymbifera* Thuret. *Acrochætium* et *Chantransia,*" in Bulletin Soc, bot. France, tome 51, 1904, the development and structure of the basal part of the species in this genus is of great systematic value when classifying these small species which are often rather alike.

1. **Acrochaetium Dwarkense** Boergs., in Kew Bulletin, 1932, No. 3, p. 114, fig, 2.

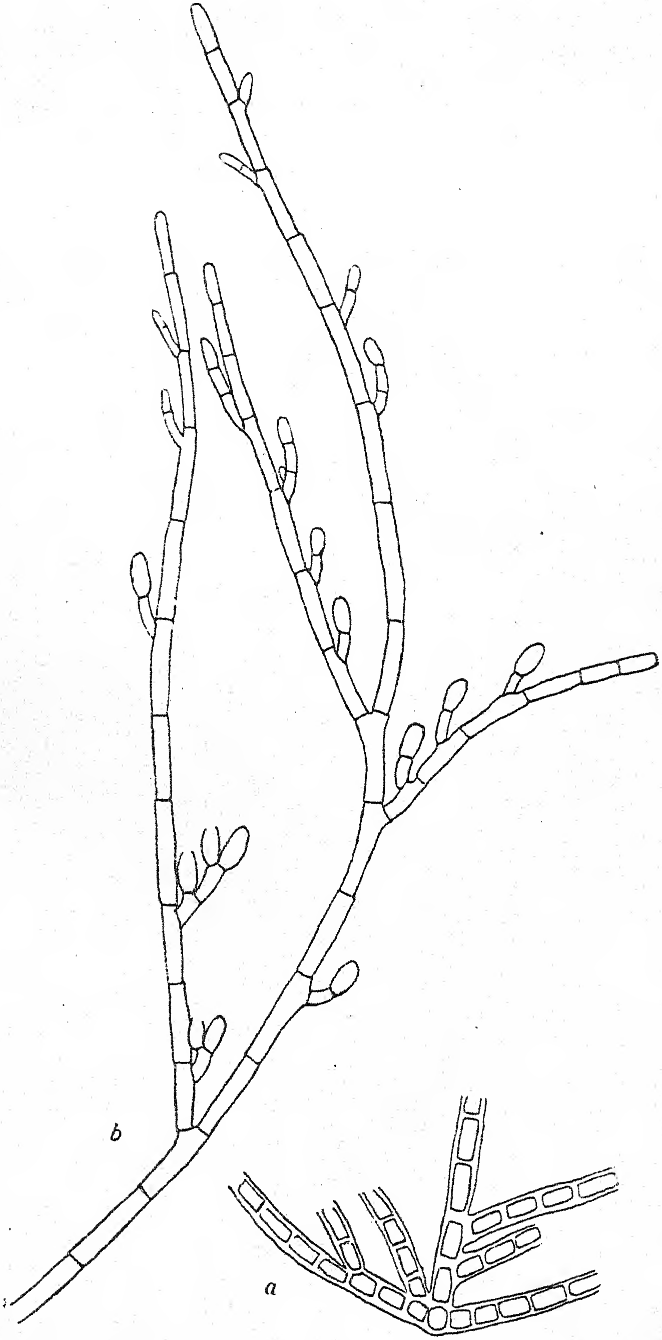


Fig. 14. *Acrochaetium Spathoglossi* nov. sp. *a*, base of a plant. *b*, upper end of an erect filament. × 750.

This fine little species occurred in masses along the edges and now and then also on the flat sides of *Padina tetrastromatica.*

India: Karvar, February 1928, leg. M. O. P. I.

Distr.: Dwarka.

2. **Acrochaetium spathoglossi** nov. sp.

Thallus ca. 300μ altus. Spora germinans, in cuticula hospitis plus minus immersa, sursum fila erecta et suberecta emittens. Fila sparse ramosa ex cellulis in inferiore parte ca. 5μ latis et 6-10μ longis in superiore ca. 3-4μ latis et 20-25μ longis. Monosporangia pedicellata aut in ramulis bi-tri-cellularibus sessilia ca. 7μ longa et 3-4μ lata.

India: Tuticorin, on the thallus of *Spathoglossum asperum*, February 1921, leg. M. O. P. I.

This small plant (fig. 14) reaches a height of about 300μ From the basal cell which appears to be somewhat sunk into the cuticle of the host several filaments arise ((fig. 14, *a*). The main filament given off from the upperside of the basal cell is erect whereas those issuing from the sides of the basal cell are at first more or less prostrate bending gradually upwards. The basal cell is about 5μ broad, and the cells next to it in the filaments are likewise short increasing slowly in length upwards. Higher up in the filaments the cells are 3-4μ thick and about 20-25μ long. The cells contain a parietal often deeply divided chromatophore with a rather large pyrenoid. The ramification of the filaments begins near the base. The branches are scattered and given out irregularly at different intervals. The monosporangia are pedicellate or rarely sessile. The pedicellate sporangia occur on the main filaments and branches, the sessile sporangia on short branchlets with two or three cells. The monosporangia are oval-oblong in shape and about 7μ long and 3-4μ broad.

The base of this plant reminds one of *Acrochaetium dwarkense* Boergs. (in Kew Bull. 1932, p. 114), but this species is more robust with thicker cells and opposite branches.

3. **Acrochaetium Tuticorinense** nov. sp.

Thallus cæspitosus usque ad 500μ altus, e disco basali parvo unistrato et filis erectis ramosis compositus. Fila erecta sparse ramosa e cellulis 7-9μ crassis et ad 25μ longis, chromatophorum parietale pyrenoide instructum, continentibus composita. Pili longi adsunt. Monosporangia sessilia, obovate-ellipsoidea, alternantia aut opposita, 17μ longa et 7μ lata.

India: Tuticorin on a piece of a sea-grass, leg. M. O. P. I.

On an old piece of a sea-grass, a small *Acrochaetium* (figs. 15, 16) was found. Its base consisted of a small roundish disc composed of a single layer of cells developed from the original

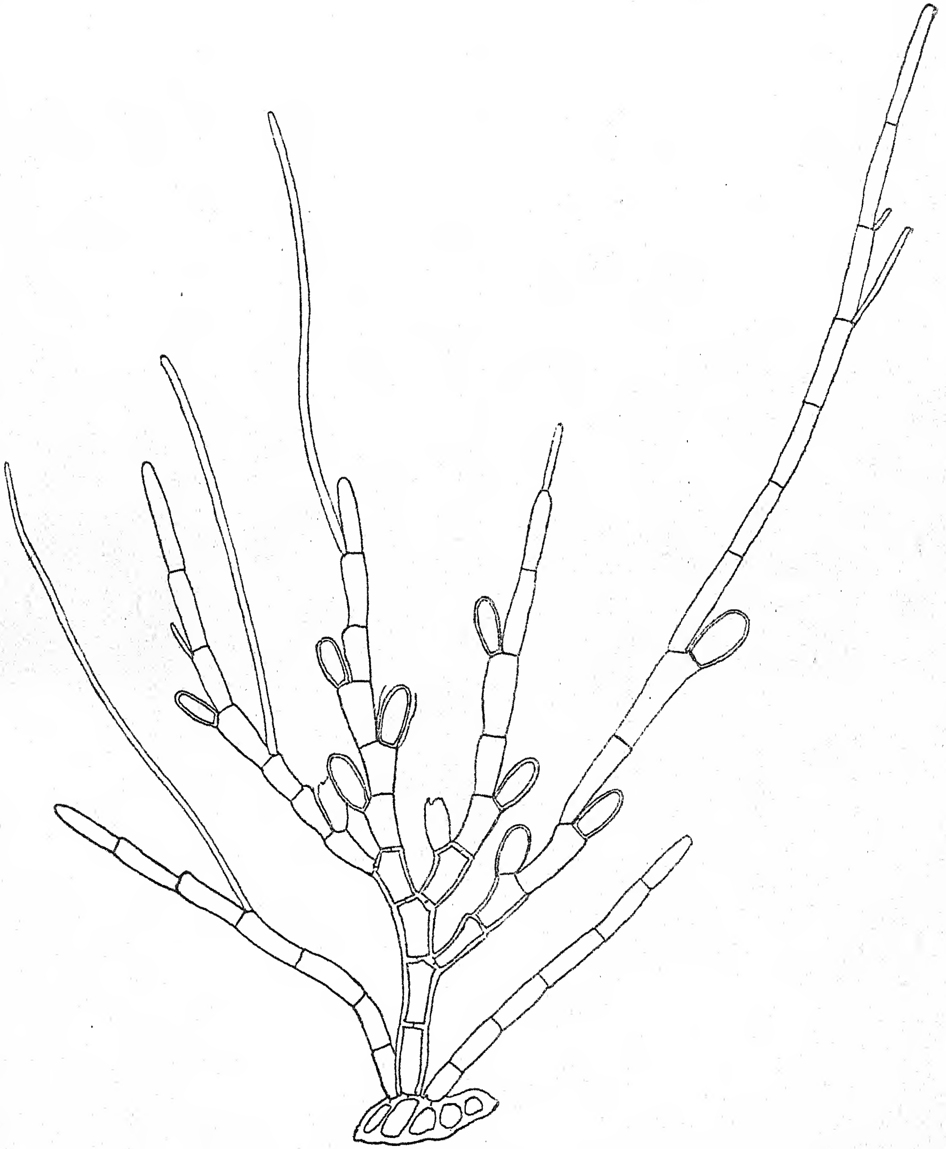


Fig. 15. *Acrochaetium Tuticorinense* nov. sp. Habit of a plant with monosporangia. × 600.

spore. From this disc the erect filaments arise and as several filaments are often given off, the plant forms small tufts reaching a height of about 500μ or more. The erect filaments near the base have cells with thick walls and the cells become a little thicker at the upper ends, being about 7-8μ thick at their base and about 9-10μ at their upper end. Higher up in the filaments the cells become gradually thinner, and at the same time cylindrical, the uppermost cells being only about 4-5μ thick. In the basal part the cells are about 15μ long, in the upper terminal parts about 25μ long. The cells contain a parietal plate-shaped chromatophore with a pyrenoid. Hairs are given off now and then from the cells. Vigorous branches are provided with scattered, rarely opposite, branchlets. The monosporangia are sessile, ellipsoidal-subcylindrical about 17μ long and 7μ broad. A single sporangium or often two oppositely placed ones are formed at the upper ends of the cells. When a sporangium has been emptied a new one is often developed. The upper ends of the filaments have thin, long and cylindrical cells and are bare without any branches or sporangia.

This *Acrochaetium* shows a certain amount of resemblance to *Acrochaetium canariense* Boergs. in Mar. Alg. Canary Islands, III Rhodophyceæ, part 1, 1927, p. 17-21, figs. 9-11; but the Canarian plant is nevertheless very different. Thus for instance the cells are shorter, the sporangia often pedicellate, and tetrasporangia are often present.

4. **Acrochaetium Krusadii** nov. sp.

Thallus cæspitosus ca. 300μ altus ex filis repentibus in thallo hospitis (*Dictyota Bartayresiana*) epiphyticis et ex filis erectis ramosis compositus. Fila repentia ex cellulis brevibus ca. 6-7μ longis et 5μ latis formata. Fila erecta in parte basali simplicia, in superiori parte plus minus ramosa, ramos sparsos breves gerentia. Cellulæ cylindricæ in parte basali 4-5μ latæ et 12-13μ longæ ad apicem versus ca. 3½-4μ latæ et 17-19μ longæ. Monosporangia pedicellata aut raro sessilia, oblonga, 8μ lata et 12μ longa.

India: Krusadi Island. May 1924, leg. M.O.P.I.

On old parts of the thallus of *Dictyota Bartayresiana* a small *Acrochaetium* (figs. 17 to 19) with creeping basal filaments was found. It forms rather small dense tufts about 300μ high. The creeping filaments are composed of rather short, more or less barrel-shaped cells, about 6-7μ long and 5μ broad. From the cells of these creeping filaments, erect filaments which are not much branched arise. The latter are composed of cylindrical cells, which are about 4-5μ thick and 12-13μ long near the base tapering a little upwards to a thickness of about 3½-4μ. The length of the cells varies very much; generally the cells become a little longer upwards being about 17-19μ long, but filaments are found in which the cells near the summit are only about 8μ

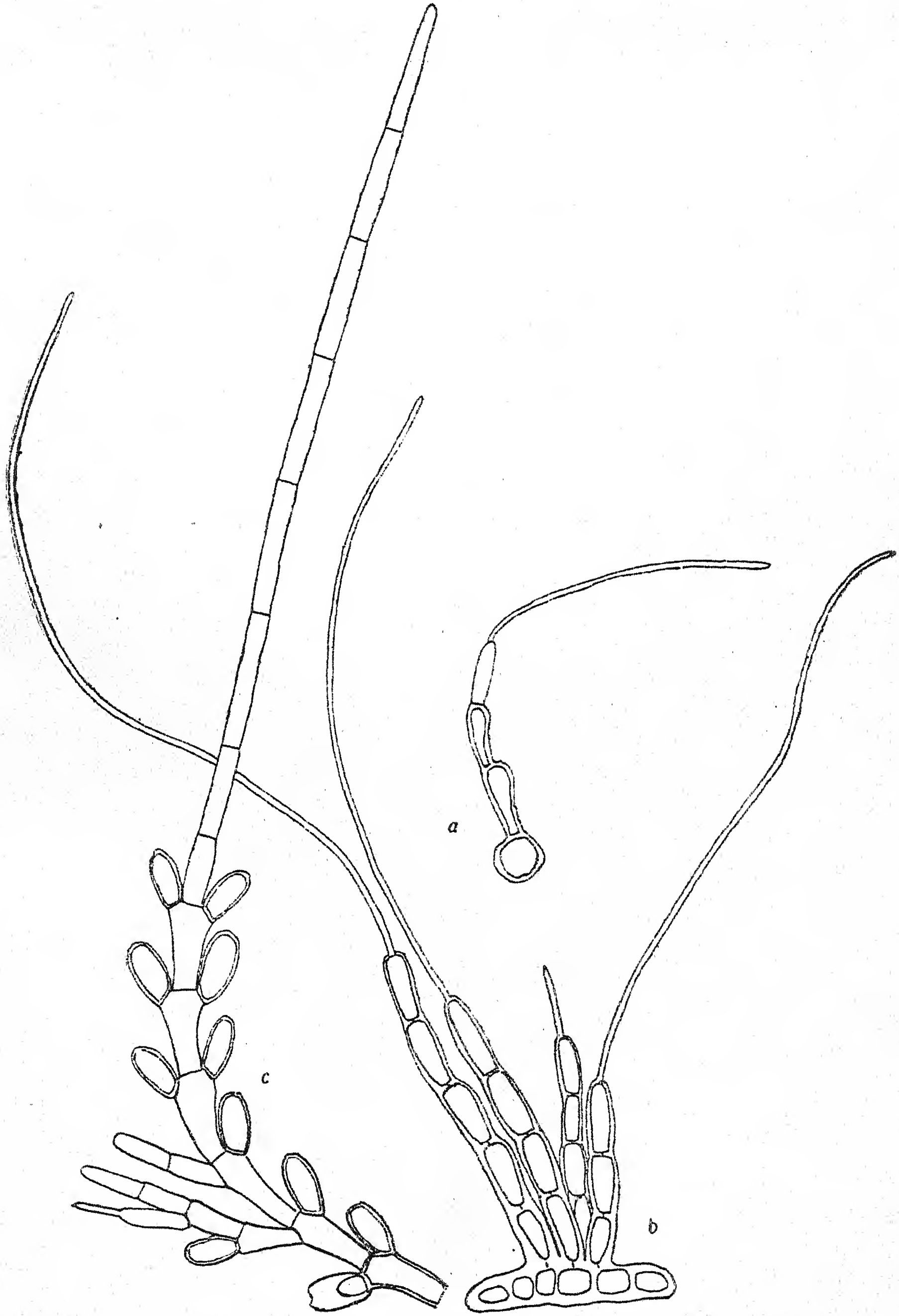


Fig. 16. *Acrochaetium Tuticorinense* nov. sp. *a*, a young plant. *b*, somewhat older plant. *c*, upper end of a filament with monosporangia. × 700.

long. Most of the filaments are unbranched, but some are provided with a few short branches. As a rule the sporangia are pedicellate or rarely sessile; often they are placed serially in long rows and sometimes alternately. The sporangia are proportionately large, oval, 8μ thick and 12μ long. The walls of the emptied sporangia become rather long, about 15-19μ; generally a new sporangium is developed from the bottom of the emptied one. No hairs are found.

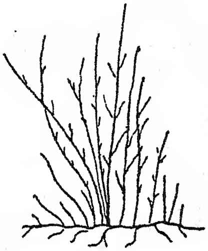


Fig. 17. *Acrochaetium Krusadii* nov. sp. Habit of plant. × 100.

The creeping basal filaments of this plant may remind one of *Acrochaetium Iyengarii* Boergs., in Kew Bulletin, 1933, p. 113, but in other respects the last mentioned plant differs very much from it, for instance, it has no hairs, the sporangia are often sessile and the basal filaments become coherent forming a disc.

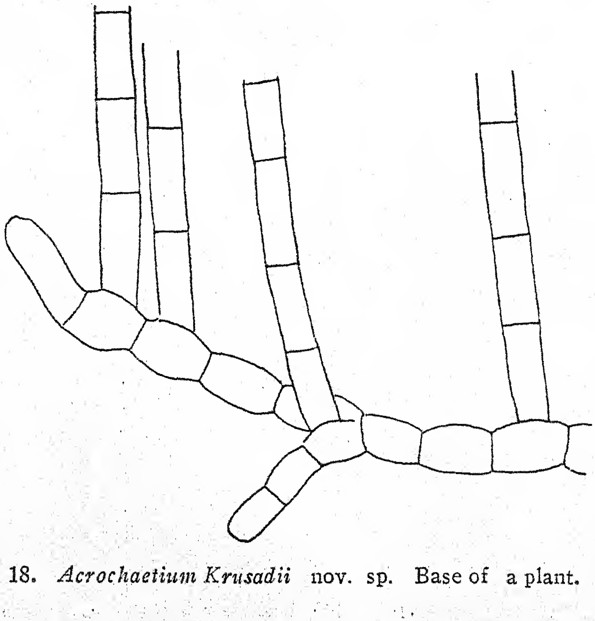


Fig. 18. *Acrochaetium Krusadii* nov. sp. Base of a plant. × 1400.

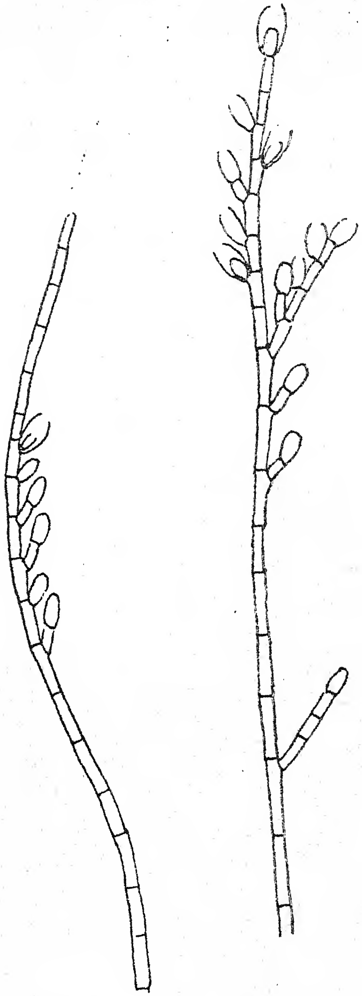


Fig. 19. *Acrochaetium Krusadii* nov. sp. Upper ends of erect filaments with monosporangia. × 500.

5. **Acrochaetium liagoraefilum** nov. sp.

Thallus cæspitosus, usque ad 300-400μ altus. Spora in filamentis assimilationis hospitis (*Liagora erecta*) germinans, magna, ca. 12μ lata, subglobosa, ex parte inferiore fila decumbentia, endophytica, ex parte superiore fila erecta emittens. Fila endophytica circa filamenta assimilationis hospitis repentia et passim fila erecta sporangifera emittentia. Fila erecta, sparse ramosa ex cellulis ad basin ca. 6-7μ latis et 2-3 plo latioribus, ad

apicem versus paullo attenuatis ca. 5μ latis. Monosporangia pedicellata, oblonge ovata, ca. 10-12μ longa et 5-7μ lata.

India : Mahabalipuram (The Seven Pagodas), leg. M.O.P.I.

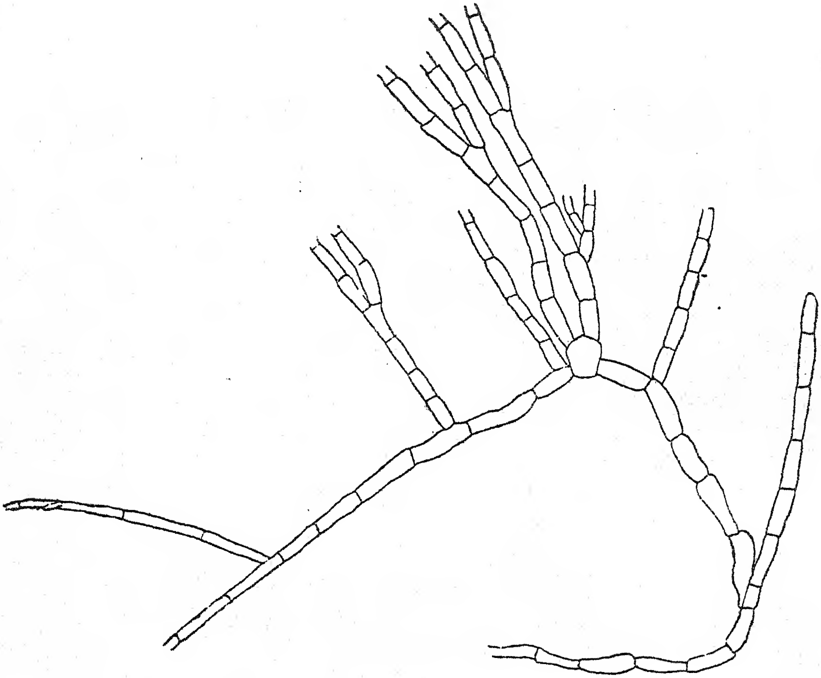


Fig. 20. *Acrochaetium liagoraefilum* nov. sp. From the spore (seen in the middle) erect filamentsand decumbent endophytic filaments issue. And from the latter erect filaments are given out. × 500.

On *Liagora erecta* Zeh this small *Acrochaetium* (figs. 20, 21) was found intermingled with other epiphytes forming small tufts about 300-400μ high. It has a spreading system of decumbent endophytic filaments creeping round about the assimilating filaments of the host and from which the erect filaments arise forming tufts above the surface of the host.

The germinating spore (compare fig. 20) is rather large about 12μ in diameter and sends out erect filaments from its upper side and decumbent creeping ones from near its base. The cells in the decumbent filaments are about 4-6μ broad and 3-5 times as long. The erect filaments at the base are about 6-7μ broad and 2-3 times as long; the filaments taper gradually upwards to a thickness of about 5μ near the top, and the cells also gradually become longer, about 22μ. The filaments and the main branches are branched. The branches are scattered. Only monosporangia are found. These are placed terminally on pedicels consisting of one or two cells. The sporangia are oval-ovate in shape, and about 10-12μ long and 5-7μ broad.

The growth of this plant reminds one of that of *Acrochaetium* (*Chantransia*) *nemalionis* (De Not.) according to ROSENVINGE's very minute description in Mar. Alg. of Denmark, p. 126. (Kgl. danske Vid. Selsk. Skrifter, 7. Række, Naturv.-mathem. Afd. VII, 1. Koebenhavn 1909), but this plant is much larger and differs very much from the Indian plant in other respects as well.

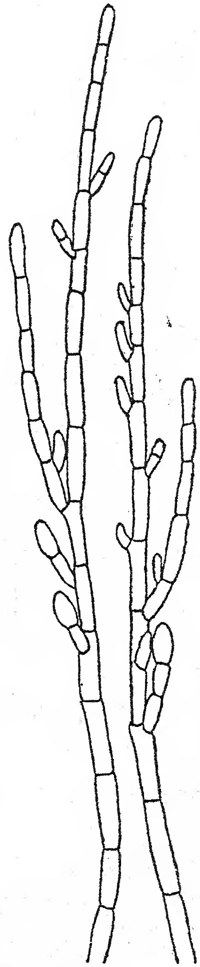


Fig. 21. *Acrochaetium liagorae-filum* nov. sp. Upper ends of erect filaments. × 500.

6. **Acrochaetium multisporum** nov. sp.

Præter sporangia tota planta endophytica e filamentis inter cellulas hospitis (*Halymenia floresia*) repentibus composita. Filamenta parce ramosa, ramos remellosos, breves, plus minus erectos gerentia.

Cellulæ plus minus cylindricæ aut sinuosæ vel interdum magis irregulares, ca. 5-10μ latæ et 3-4-10 plo longæ, chromatophorum latum parietale sæpe per totam longitudinem plerumque in duas, inderdum in plures partes divisum continentes. Sporangia terminalia, pyriformia, supra superficiem hospitis plus minus emergentia, ca. 22μ lata et 26μ longa, sporas numerosas continentia.

India: Pearl banks, near Tuticorin, leg. M. O. P. I.

In the soft loose thallus of a male plant of *Halymenia floresia* a part of the thallus was in some places infected with a peculiar small endophytic *Acrochaetium* (figs. 22, 23). The thallus consists of an endophytic ramified system of branches inside the thallus of the host plant above the surface of which only the sporangia of the endophytic alga protrude. Its filaments are composed of cells which are rather long in the unbranched parts and rather short in the branched ones, the length of the cells varying from often not longer than the breadth up to several times the breadth. The cells are about 5-10μ broad and up to 75μ long, and sometimes even up to 100μ long. The filaments are often almost straight and these parts help to spread the plant round about in

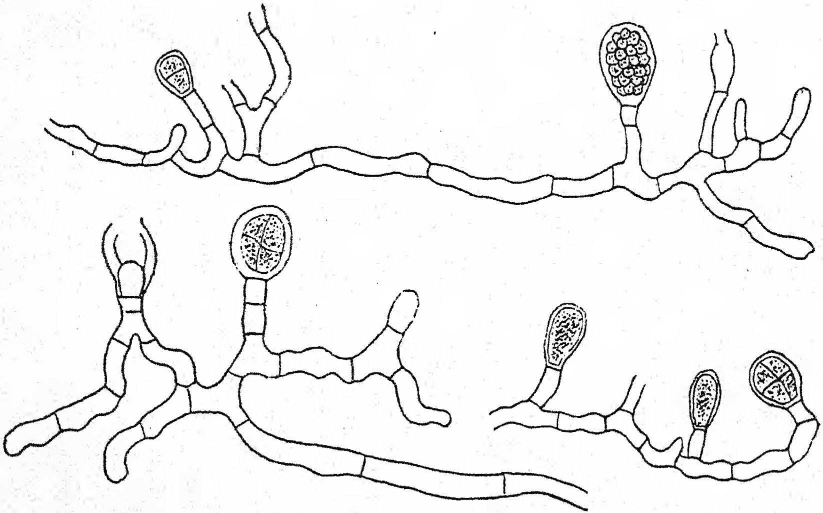


Fig. 22. *Acrochaetium multisporum* nov. sp. Part of the thallus with sporangia in various stages of development. × 400.

the host; sometimes they are irregularly bent with short sinuous cells. From the creeping filaments systems of short branches are given out, the upper ends of which pierce the surface of the host and are transformed into sporangia. In an infected part of the thallus of *Halymenia*, the sporangia of the *Acrochaetium* are seen scattered over the surface. The cells contain a large parietal chromatophore which in many of the cells is divided longitudinally into two long ribbon-like bodies, and in the other cells are further divided transversely into smaller ones. No pyrenoid was observed, most probably because the material had remained too long in formalin.

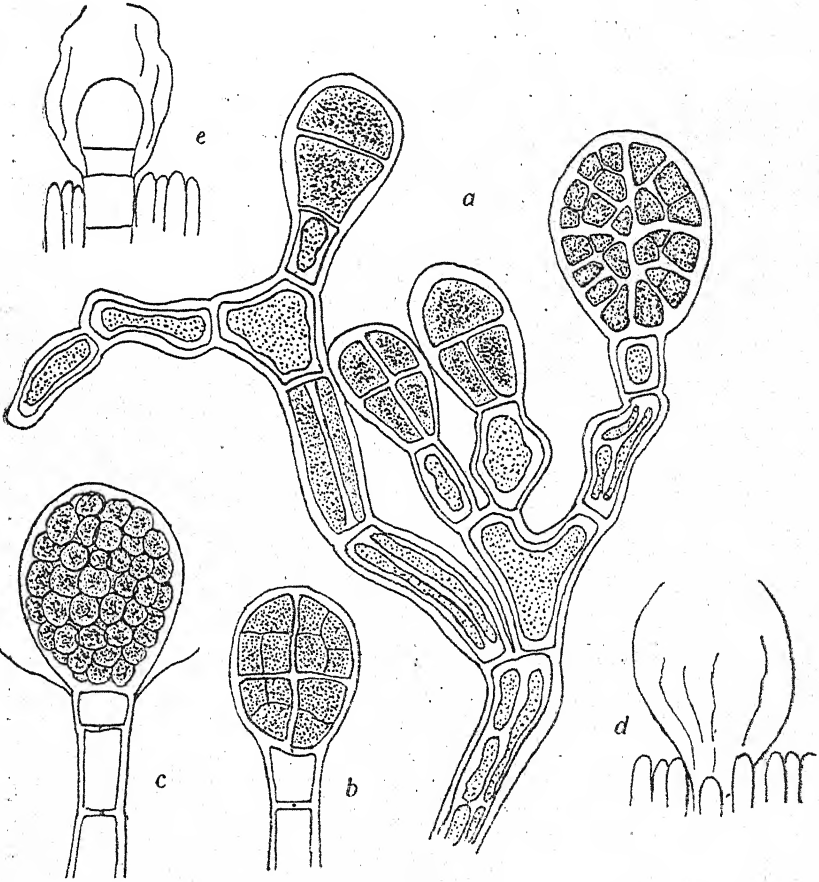


Fig. 23. *Acrochaetium multisporum* nov. sp. *a*, part of the thallus with sporangia in various stages of development. *b*, sporangium in division. *c*, a nearly ripe sporangium. *d*, an emptied sporangium surrounded by epidermal cells of the host. *e*, a new sporangium growing up in an emptied one. × 1100.

The terminally placed obovate-pyriform sporangia in the first place are divided by a transverse wall into two cells and then by longitudinal walls into four parts, which are again divided into a large number of small spores. When they are ripe they are emptied through a large hole in the upper end of the wall; empty sporangia were found here and there between the unemptied ones. When a sporangium is empty, a new one is often formed in the place of the old one. The sporangia are about 22μ broad and 20μ long.

As far as I know, polyspores in *Acrochaetium* have only been found once, namely, by Howe in *Acr. polysporum* Howe (Mar. Alg. of Peru, Memoirs of the Torr. Bot. Club., vol. XV, 1914, p. 88, pl. 31, figs. 1-11). But in no other respects do these two plants resemble each other.

In its method of growth, the Indian plant shows some likeness to *Acrochaetium Collinsianum* Boergs. in Mar. Alg. D. W. I., vol. II, p. 454 (Syn. *Acrochaetium liagorae* Boergs. l.c., p. 57, figs. 60-62); but otherwise the last mentioned species is very different, having for instance monosporangia only and hairs.

7. **Acrochaetium liagoroides** nov. sp.

Thallus ex parte majore endophyticus ex filamentis decumbentibus irregulariter ramosis inter filamenta assimilatoria hospitis (*Liagora erecta* Zeh) circumvagantibus et ex filamentis erectis, ramosis, tetrasporangiferis compositus. Filamenta decumbentia ex cellulis nunc subcylindricis, nunc plus minus fusiformibus, nunc medio plus minus irregulariter inflatis, ca. 4-6μ-13μ latis et 22-26μ longis, chromatophorum stellare pyrenoide centrali continentibus, constructa. Filamenta erecta plus minus repetite divisa, ex cellulis ad superficiem hospitis versus gradatim brevioribus et oblonge-rotundatis formata. Tetrasporangia, ex cellulis extremis filamentorum orta, oblonga, 12-13μ lata et 17-18μ longa.

India: Mahabalipuram (The Seven Pagodas), leg. M.O.P.I.

In *Liagora erecta* Zeh an endophytic *Acrochaetium* (fig. 24, 25) was found which I have called by the above mentioned name because of its very great likeness to the tissue of the host (compare fig. 25). When I first observed it, I must confess that I thought, intermingled as it was between the assimilating filaments of the host, that it belonged to the *Liagora*, and therefore supposed that I had found a species of *Liagora* with real true tetrasporangia. And it was not only the shape and the size of the filaments of the host and of the endophyte which were so very much alike, but the chromatophores also of both the plants resembled each other very much. Thus the chromatophores in *Liagora* as well as in *Acrochaetium* were very feebly developed in the filaments creeping in the interior of the host, they consisted merely of a few long thread-like prolongations which issued at both sides from the pyrenoid in the middle of the cells, whereas in both the plants the chromatophores gradually increased in size and vigour in filaments approaching the surface of the host. But I still felt some doubt as to the matter

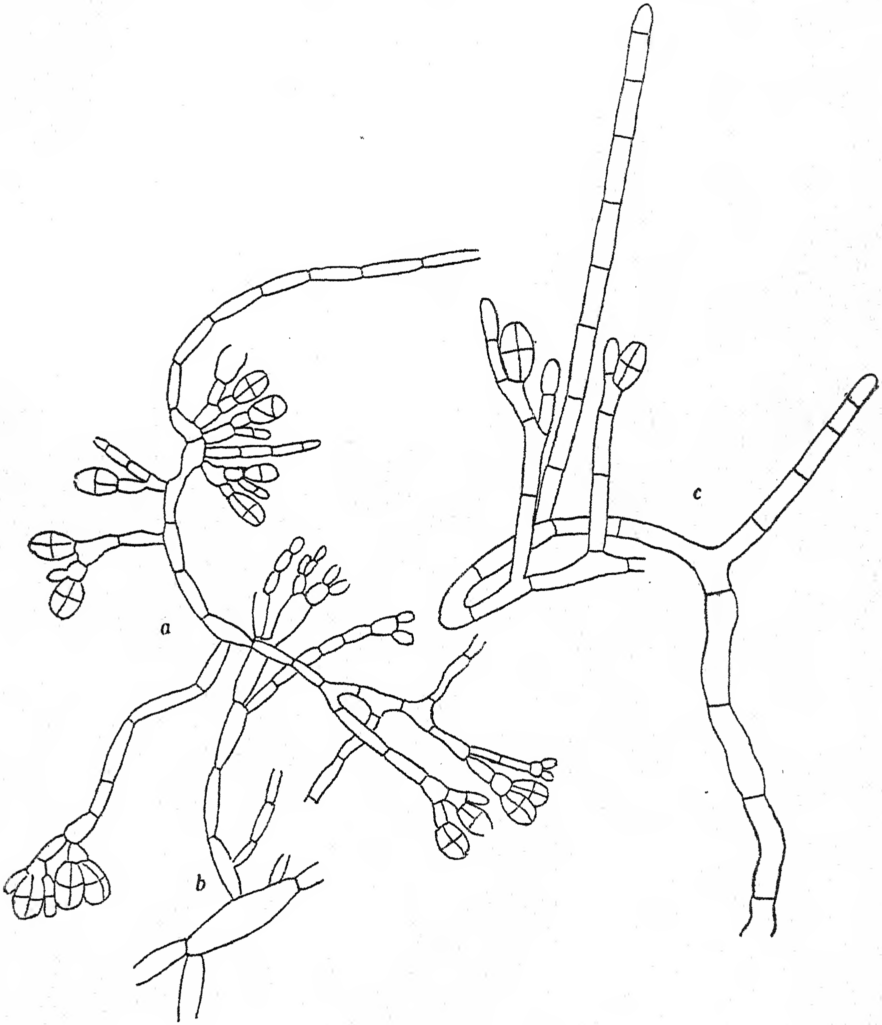


Fig. 24. *Acrochaetium liagoroides* nov. sp, *a*, part of thallus with tetrasporangia. *b*, a filament of *Liagora erecta*. *c*, part of the thallus with erect filaments. × 325.

and after having examined some fresh material I came across short filaments in some specimens and most probably these filaments have protruded above the surface of the host, and they quite resembled *Acrochaetium* having almost cylindrical cells and a large chromatophore filling nearly the whole cell (compare fig. 24c). But such filaments do not seem to be common. As a rule the upper ends of the filaments with tetrasporangia lie just near the

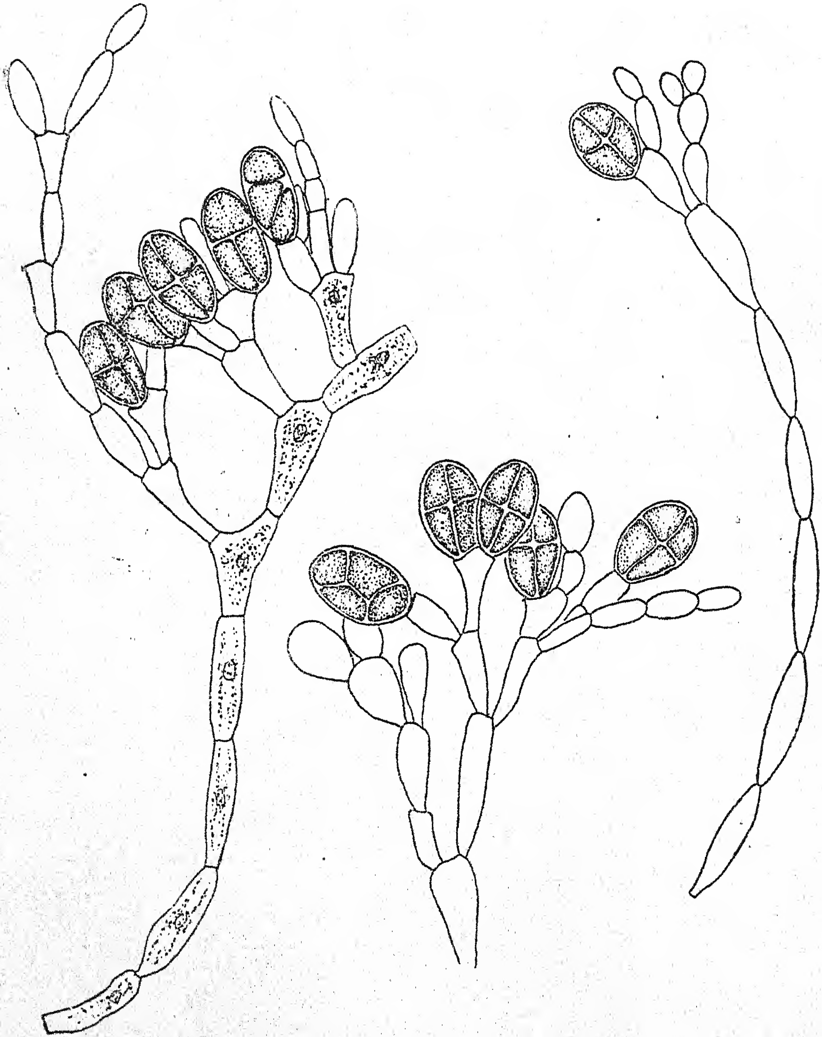


Fig. 25. *Acrochaetium liagoroides* nov. sp. Parts of the thallus with tetrasporangia. × 650.

upper ends of the assimilating filaments of *Liagora*. The filaments more deeply immersed in the tissue of the host are rather long, nearly cylindrical or fusiform, about 22-26μ long and 5-6μ at their thickest and about 4μ only at the ends. But thicker, irregularly shaped cells up to about 12-13μ are also found. Towards the periphery, the filaments generally increase in thickness, often up to about 12μ or more, while the cells become shorter and oval in shape. At the same time, the chromatophores become more vigorously developed as mentioned above. The few filaments protruding above the surface of the host have nearly cylindrical cells with a large parietal chromatophore covering the whole or almost the whole cell ; these cells are about 6μ thick and 2-4μ times as long.

The tetrasporangia are developed in the upper ends of the filaments. They are oval in shape, and about 17-18μ long and 12-13μ broad. They are cruciately or sometimes more irregularly divided. They are developed from the end cells in the filaments; when a sporangium is emptied, a new one may begin to grow out in the place of the old one.

Several species of *Acrochaetium* have been found on *Liagora*. Among these *Acrochaetium Collinsianum* Bœrgs. (Mar. Alg. D. W. I., vol. II, p. 454) seems to be related to this species. But the West Indian plant differs essentially from the Indian plant in having monosporangia only and also in having these monosporangia often placed directly on the creeping filaments either sessilely or pedicellately. Another difference is that hairs are present in the West Indian plant, while they are absent in the Indian plant.

Fam. 2. ***Helminthocladiaceae.***

Liagora Lamouroux.

Liagora erecta Zeh, Neue Arten der Gattung *Liagora* (in Notizblatt des Königl. bot. Gartens und Museums zu Berlin, V. Bd. 1913, p. 268).

When I refer some specimens in Professor Iyengar's collection to this species, I must point out that it is because the ramification of Zeh's plant seems to be the same as that of Iyengar's plants and because of the locality, Madras, being the same. By the courtesy of Dr. Otto Chr. Schmidt and the Direction of the Botanical Museum in Berlin-Dahlem, I was allowed to see the original specimen of this species. It consists only of a small piece about 9 cm. high of a main axis provided with a few scattered short branches. From the description of the locality, "Madras Beach," attached to the specimen, it is evidently a bit of a bleached specimen cast ashore on the extensive sandy coast at Madras. An examination of a small decalcified bit of it also shows that the upper ends of the assimilating filaments are torn away more or less, but nevertheless, I think, the specimen is from a male plant, and the assimilating filaments, when compared with those in my specimens, seem to agree very well in shape and size. But I wish to point out that, in case this species was established on my material and I had to identify the original specimen of ZEH's by means of it, I would feel a little doubtful.

During a visit to London just now at the end of March and the beginning of April 1936, Dr. TANDY allowed me to see the specimens of this species found in the British Museum. The small fragment found in Berlin was taken from one of the specimens. These specimens agree very well with mine, the only difference being that the lower branches were less developed.

The material which I have examined consists of a large dried male plant (see pl. I) and a few smaller female plants likewise dried (one of these seen to the right on the plate) and finally several pieces of specimens with numerous epiphytes preserved in formalin. The large male plant is 40 cm. high. Besides the main filaments two filaments almost as long and 5-6 short ones about 14 cm. long issue from the base. Both the main filaments and the other filaments from top to base are provided with short scattered branches, the lowermost reaching a length of about 14 cm., the remaining ones becoming gradually shorter upwards, the uppermost reaching only a length of ½-1 cm. The lowermost branches are ramified like the main filament. The plant has a dirty reddish-brown colour, but it is rather difficult to decide its real colour on account of the epiphytes with which it is covered.

The female specimens are much smaller being only 12 cm. high. In these several branches are likewise given off from the basal disc, and these branches are covered with short scattered branchlets. As regards the anatomy of the plant, it is built in the usual way as found in *Liagora*. After decalcification the assimilating filaments issuing from the medullary filaments are found to be composed of long fusiform cells becoming gradually shorter and thicker upwards and then decreasing a little near the periphery. In the female plant the basal cells of the filaments are especially long and thin and about 5-6μ thick; almost in the middle of them, where they begin to be a little thicker, the carpogonial branch is developed. Next to the external habit of the plant, the shape of the carpogonial branch seems to be one of the best characters to determine the species of this genus, whereas in my opinion the shape and size of the assimilating filaments vary very much even in the same species. The carpogonial branch (fig. 26 a, b) in this species is rather much curved in the basal part reminding one very much of the one found in *Liagora gymnarthron* Boergs. (Mar. Alg.

Can. Islands, III, 1, p. 56, fig. 31), but it is longer and thinner and about 5-6μ broad only. It consists of 4 cells, 3 short ones and a long straight carpogonium about 13-15μ long tapering gradually upwards and ending in the long thin trichogyne. The upper cells in the assimilating filaments are oblong about 5-8μ broad. The cystocarps form large globular bodies composed of the densely aggregated sporogenous filaments surrounded by a well developed involucrum composed of long thin incurved filaments.

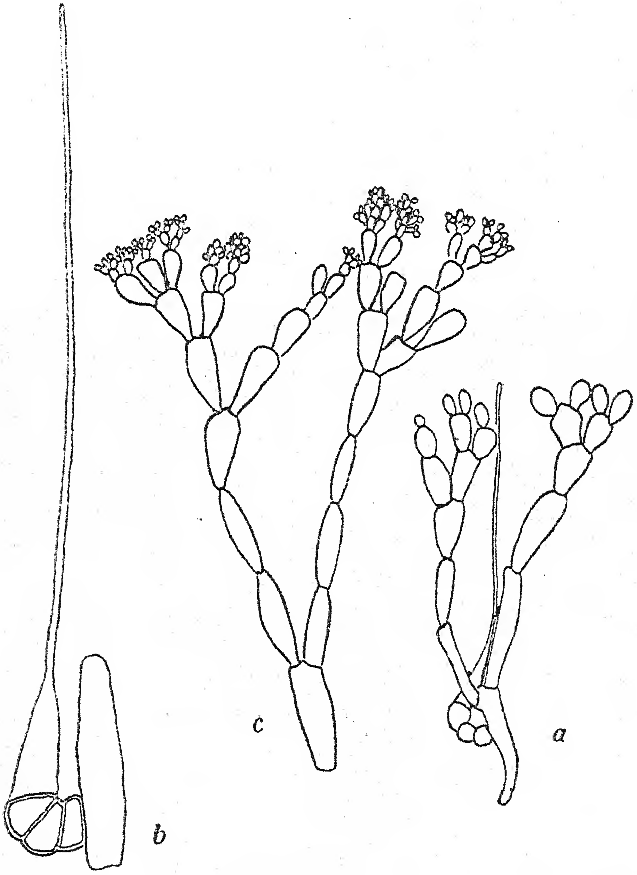


Fig. 26. *Liagora erecta* Zeh. *a*, assimilating filaments with carpogonial branch, *b*, a corpogonial branch more magnified. *c*, filaments with antheridia. *a*, *c*, × 500. *b*, × 800.

In the male plant the antheridia (fig. 26c) are formed at the ends of the assimilating filaments.

Neither in this species nor in those I have seen from India have I met with the peculiar endophytic organisms which were so common in some of the West Indian species of *Liagora* (compare my description and figures in Mar. Alg. D. W. I., vol. II, p. 455-8, fig. 421). But Mme. WEBER found them in *Liagora cheyneana* Harv. (=*Liagora farinosa* Lamx.) as mentioned in her Liste des Algues du Siboga, p. 201. These bodies, which, I think, are independent organisms living in the tissue of the host, are supposed by HOWE to be monosporangial discs (compare HOWE's paper, Observations on monosporangial discs in the genus *Liagora* in Bull. Torr. Bot. Club, 47, p. 1-8, pl. 1, 1920).

The plant was found in a very exposed locality in the month of January.

India: Mahabalipuram (The Seven Pagodas), leg. M.O.P.I.

Distr.: Madras.

II. Gelidiales.

Fam. 1. ***Gelidiaceae.***

Gelidium Lamour.

1. Gelidium corneum (Huds.) Lamour. Cfr. BOERGESEN in Kew Bull. 1934, No. 1, p. 5.

Some specimens agree with my figure in Mar. Alg. D.W.I., vol. II, p. 115, fig. 124; others are very like KÜTZING's figure in Tab. Phyc., vol. 18, pl. 59, called *Gelidium micropterum*.

India: Carvar, Bengi Bay, !.

Distr.: Widely spread in warmer seas.

III. Cryptonemiales.

Fam. 1. ***Rhizophyllidaceae.***

Chondrococcus Kütz.

1. Chondrococcus Hornemanni (Mert.) Schmitz. in Engl. Bot. Jahrb. XXI, p. 170, 1895. BOERGESEN in Kew Bull., 1933, No. 3, p. 117.

India: Cape Comorin, leg. M.O.P.I.

Distr.: Indian Ocean.

Fam. 2. ***Corallinaceae.***

Amphiroa Lamour.

1. **Amphiroa anceps** (Lamk.) Decne. Cfr. Boergesen in Kew Bull., 1934, p. 7.

India: Carvar,!; Cape Comorin (a form with a more narrow thallus), leg. M.O.P.I.

Distr.: India, South Africa, Malay Archipelago, Japan, West Australia.

Fam. 3. ***Grateloupiaceae.***

Halymenia C. Ag.

1. **Halymenia floresia** (Clem.) Ag., Spec. Alg. I, p. 209 J. Agardh, Spec. Alg. II, p. 205; Epicrisis, p. 138.

A few fine specimens were collected by Iyengar from pearl oyster banks near Tuticorin and from Chank Fisheries banks near Rameswaram.

Distr.: Warmer Atlantic Ocean, Mediterranean Sea, West Indies, Malayan Archipelago.

IV. Gigartinales.

Fam. 1. ***Solieriaceae.***

Soliera J. Ag.

1. **Soliera robusta** (Grev.) Kylin. Cfr. Boergesen in Kew Bulletin, 1934, No. 1, p. 10.

Only a few cystocarpic specimens have been found; they were gathered at the end of February.

India: Tuticorin!

Distr.: Australia, Japan, Malayan Archipelago, India.

Fam. 2. ***Hypneaceae.***

Hypnea Lamour.

1. **Hypnea musciformis** (Wulf.) Lamour. Cfr. Boergesen in Kew Bull. 1934, p. 17, for more literature.

India: Tuticorin, leg. M.O.P.I.

Distr.: Most warm seas.

2. **Hypnea valentiae** (Turn.) Mont. Cfr. Boergesen in Kew Bull. 1934, p. 17.

Hauck in Hedwigia, 26, 1887, p. 20, has pointed out that several species formerly considered separate, namely, *H. seticulosa*

J. Ag., *Hypnea divaricata* Kütz., *Hypnea charoides* Lamx. and others, are to be referred to *Hypnea valentiae* (Turn.) Mont. (*Fucus valentiæ* Turner, "Fuci," tab. 78, vol. II, 1809). In the paper quoted above I have followed HAUCK. In my material some specimens resemble very much LAMOUROUX's figure of *Hypnea charoides* (Essay . . . Thalassioph., 1813, pl. X, figs. 1-3); but other specimens are intermediate and vary much as to appearance. In some specimens (No. 5619 from Karvar) the branches are very much divaricate and under the acute summits they quickly become covered with densely placed short ramuli spreading on all sides and resembling very much the plant OKAMURA has described in his Algæ Jap. Exsiccatæ, No. 62, and named *Hypnea seticulosa*. This specimen forms a transition to the form which in Kew Bull. 1934, p. 18, though with reservation, I have referred to *Hypnea spicifera* and which, as pointed out there, is very like *Hypnea Harveyi* Kütz., Tab. Phycol., vol. 18, pl. 28.

India: Karvar, Bengi Bay!

Distr.: Most warm seas.

Fam. 3. *Gracilariaceae.*

Gracilaria Grev.

1. Gracilaria compressa (Ag.) J. Ag., Spec. Alg., p. 593. Epicrisis, p. 417. *Sphaerococcus compressus* Ag. Spec. Alg., p. 308.

A female specimen resembles very much KÜTZING's figure of *Sphaerococcus compressus* in Tab. Phyc., vol. 18, pl. 78 and of *Sphaerococcus vagus*, pl. 76.

India: Cape Comorin, leg. M. O. P. I.

Distr.: Warm Atlantic Ocean, Mediterranean Sea, etc., most warm seas.

2. Gracilaria foliifera (Forssk.) Boergs., Revision of FORSSKAAL's Algae in Dansk Bot. Arkiv, Bd. 8, 1932, p. 7, fig. 1.

A form with a rather narrow thallus and often with numerous proliferations along the margins was dredged by me in dirty water at a depth of about 20 feet near Hare Island, Tuticorin. At Cape Comorin Prof. IYENGAR has gathered a single female plant.

Distr.: Warmer Atlantic coasts of Europe and America, Mediterranean Sea, Red Sea, Indian Ocean, etc.

V. Ceramiales.

Fam. 1. *Ceramiaceae.*

Subfam. 1. ***Ceramieae.***

Centroceras Kütz.

1. **Centroceras clavulatum** (Ag.) Mont. Cfr. Boergesen in Kew Bull., 1934, p. 18.

Distr.: Most warm seas.

Subfam. 2. ***Spyridieae.***

Spyridia Harv.

1. **Spyridia filamentosa** (Wulf.) Harv. Cfr. Boergesen in Kew Bull., 1931, p. 14.

India: Tuticorin ; Shingly Island, leg. M. O. P. I.
Distr.: Most warm seas.

Fam. 2. *Rhodomelaceae*

Subfam. 1. ***Laurencieae.***

Laurencia Lamour.

1. **Laurencia papillosa** (Forssk.) Grev., Algæ Britannicæ, 1830, p. LII. *Fucus papillosus* Forssk., Flora Aegypt.—Arab., 1775, p. 190. Boergesen, A revision of Forsskaal's Algæ (Dansk Bot. Arkiv, vol. 8, 1932, p. 6).

India: Tuticorin, Hare Island, 28th February 1928, leg. M. O. P. I.; Krusadi Island, Pamban, May 1924, leg. M. O. P. I.

Distr.: Most warm seas.

2. **Laurencia parvula** nov. sp.

Frons cæspitosa, ca. 1,5 mm. alta, e ramis basalibus repentibus et ramis erectis aut suberectis composita. Rami basales substrato (*Lithothamnium* sp.) adfixi, subteretes, ca. 500μ lait. Rami erecti teretes aut subteretes, sparsi aut interdum oppositi, clavati, in parte basali ca. 225μ lati, superne ad 500μ lati, apice late rotundato, aut simplices aut irregulariter ramosi. Tetrasporangia et cystocarpia ignota, antheridia in superiore parte ramorum orta.

India: Krusadi Island, leg. M. O. P. I.

Among the branches of a *Lithothamnion* a small *Laurencia* (fig. 27) was found which I have not been able to refer to any of the hitherto known small species. The decumbent creeping filaments are about 500μ broad; from these filaments erect or suberect short subclavate filaments are given out about 1,5 mm. high. Often they are simple but are sometimes more or less branched. At their base the branches are about 225μ thick, the upper broadly rounded summit about 500μ. The specimens were male plants. A transverse section shows that the epidermal cells are not protruding and that the cells are not palisade-like but are as long as broad. In the medullary tissue thickened walls are found here and there. When seen from above the epidermal cells in the main filaments are elongated and polygonal about 42μ long and 12μ broad with very thick walls; in the erect branches they are smaller.

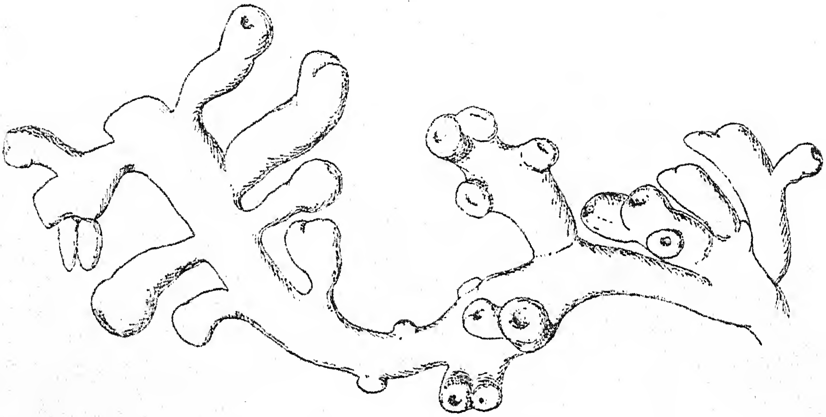


Fig. 27. *Laurencia parvula* nov. sp. Part of the thallus. × 10.

This small *Laurencia* is perhaps most related to *L. pygmaea* Web. v. Bosse (in Mar. Alg. Sealark Exp. in Trans. Linn. Soc. Bot., vol. VIII, 1914, p. 122) but the thallus of the Indian plant is more robust and the tufts on the other hand shorter.

3. Laurencia flagellifera J. Ag., Spec. Alg., vol. 2, p. 747; Epicrisis, p. 648. YAMADA, Notes on *Laurencia*, p. 197.

When I refer a specimen in IYENGAR's collection to this species at first described on material from India, I must point out that I have not been able to compare it with the original material but it agrees very well with J. AGARDH's description. The plant (fig. 28) forms dense tufts about 8-9 cm. high, the erect vertical terete densely placed filaments (about $1\frac{1}{4}$-$1\frac{1}{2}$ mm. thick) issuing from a large basal disc firmly fixed to the rock. Many of the filaments are quite unbranched, some become branched in

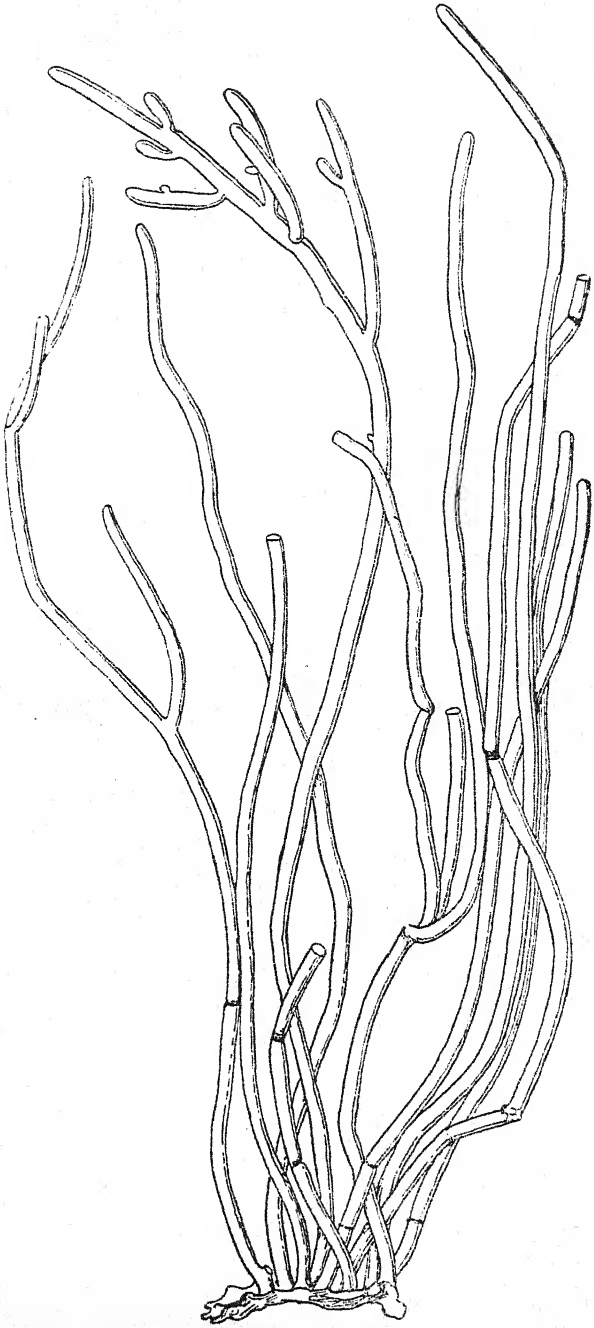


Fig. 28. *Laurencia flagelliformis* J. Ag. Part of the thallus. About × 2.

the upper parts. The branches are directed upwards and cylindrical with somewhat narrow bases; some of the lowermost branches are sometimes branched again. A transverse section shows that the surface cells are long, narrow and densely placed like palisades and not protruding as given in Yamada's description. On the other hand, now and then I found lenticular thickenings in the medullary tissue which YAMADA has not found.

The plant is most certainly perennial, dying down during the unfavourable season and leaving some stumps 2-3 cm. high from which the new shoots issue when the plant begins to grow again; dark annular scars are seen at the base most probably originating from the rejunenescence.

India: Cape Comorin, October 1926, leg. M. O. P. I.
Distr.: India.

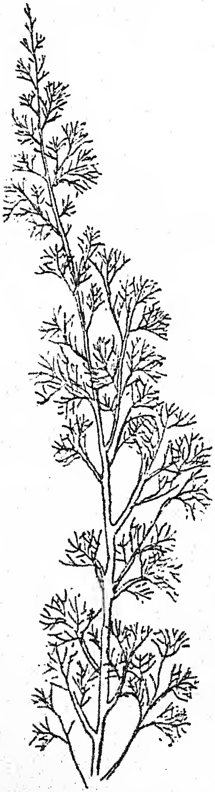


Fig. 29. *Polysiphonia unguiformis* nov. sp. Upper end of a main filament. × 6.

Subfam. 2. ***Chondrieae.***

Chondria (C. Ag.) Harv.

1. Chondria dasyphylla Ag. Sp. Alg., p. 350. Cfr. Boergesen in Kew Bull. 1932, p. 132 ; 1933, p. 133.

India: Tuticorin, Hare Island, leg M. O. P. I.

Distr.: Seems to occur in most warm seas.

Subfam. 3. ***Polysiphonieae.***

Poliysiphonia Grev.

1. Polysiphonia unguiformis nov. sp.

Thallus cæspitosus usque ad 4-6 cm. altus, ecorticatus, tetrasiphonius, articulatus. Pars basalis rhizoideis unicellularibus adfixa. Fila erecta principalia, inferne ca. 600μ lata, sursum gradatim attenuata, ramos ramelliferos gerentia. Rami in loco trichoblastorum oriuntur, quoqueversum egredientes, ca. 200μ lati; ramuli in parte basali ca. 100μ lati, superne acuti sunt.

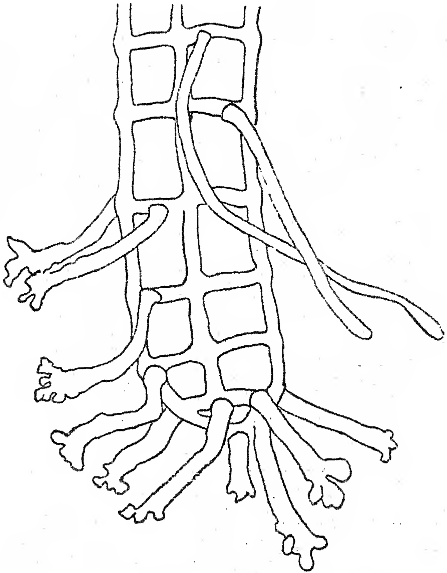


Fig. 30. *Polysiphonia unguiformis* nov. sp. Base of a plant. × 110.

Tetrasporangia subglobosa ca. 70μ lata et longa, in ramulis orta, spiraliter seriata. Cystocarpia urceolata, ca. 300μ longa et 250μ lata ostiolo apicali non protracto munita. Antheridia subcylindrica, 225μ longa et 25μ lata, superne sine cellula sterile, e ramulo basale trichoblastorum orta.

India: Shingly Island. October 1924, leg. M. O. P. I.

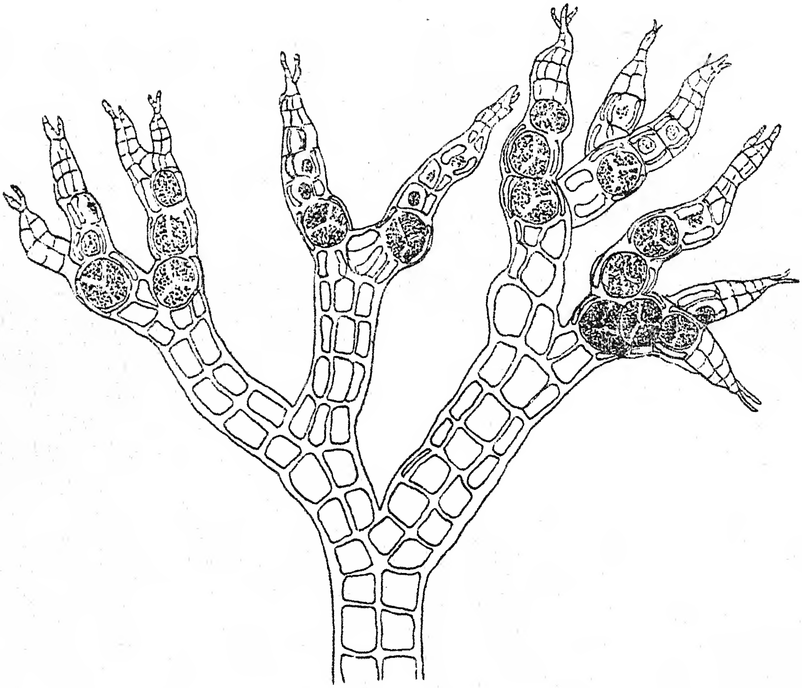


Fig. 31. *Polysiphonia unguiformis* nov. sp. Part of a tetrasporic plant. × 100.

The plant (fig. 29) forms tufts about 5-6 cm. high and was fixed by means of rhizoids to the leaves of a sea-grass, most probably *Enhalus acoroides*. The rhizoids are unicellular ending in irregularly shaped stellate discs (fig. 30). The main branches have percurrent axes and carry short scattered branch-systems, (fig. 29). These are several times pseudodichotomously divided. The uppermost ramuli taper very much upwards ending in acute apices. As the ramuli are often together in pairs with an angle of 30—40° between them, they remind one somewhat of the claws of a lobster (figs. 31, 32). The plant has 4 pericentral cells. No cortical layer is present. The trichoblasts are more or less developed in the upper ends of the filaments; they are placed in a screw turning left. Now and then a branch is produced instead of a trichoblast. The main filaments near the base are about 600μ thick and the cells about 400μ long, but the length of the cells varies very much. The filaments are often narrowed in the parts between the cross-walls. In the short branch systems, the filaments become thinner to about 200μ. At their base the branches are about 100μ thick (fig. 31, 32). The tetrasporangia (fig. 31) are formed in the upper ends of the branchlets. They are placed in a short screw, and 3-4 are developed in each row, seldom more. They are almost globular and are about 70μ broad.

The cystocarps (fig. 32) are urceolate, about 300μ long and 250μ broad and at their upper ends only 150μ broad. In each of the branch-systems 2-4 cystocarps are generally formed.

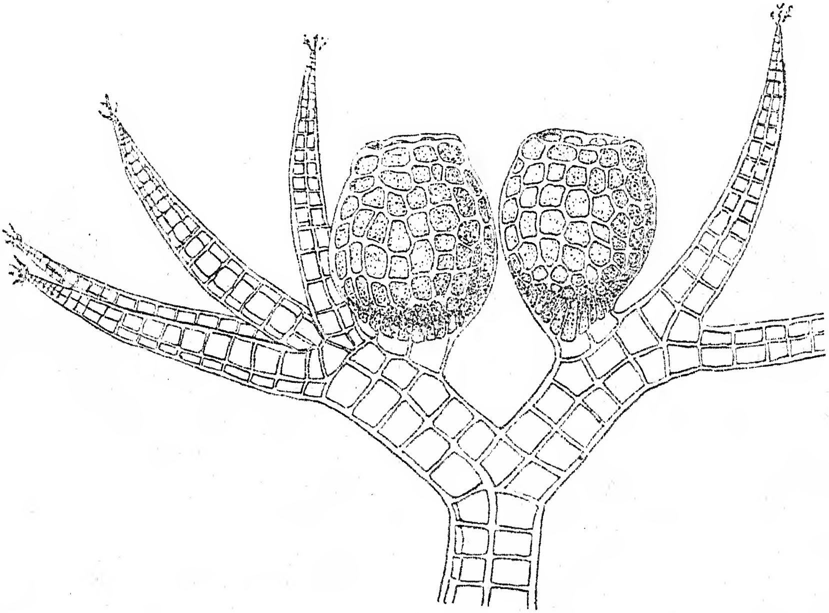


Fig. 32. *Polysiphonia unguiformis* nov. sp. Part of a female plant with cystocarps. × 120.

This species belongs to the group of *Polysiphonia* in which only a part of the trichoblast is transformed into the antheridial stand, namely, the first side branch of it (Compare: THURET ET BORNET, Etudes Phycologiques, Paris 1878, pp. 86, 87). Morover, no large sterile cells are found in the upper end of the androphores (fig. 33) which are elongated-ellipsoidal in shape and about 225μ long and 35μ broad, when fully developed.

Subfam. 4. **Polyzonieae.**

Leveillea Decsne.

1. Leveillea jungermannioides (Mart. et Her.) Harv. Cfr. BOERGESEN, Mar. Alg. Arabian Sea, p. 49.

India: Tuticorin, Hare Island!

Distr.: Red Sea, Indian Ocean, Australia.

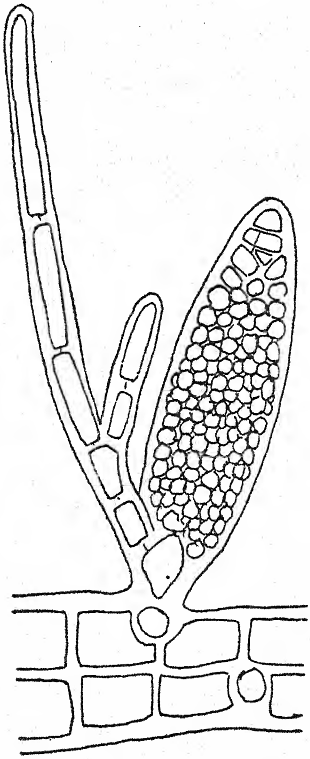
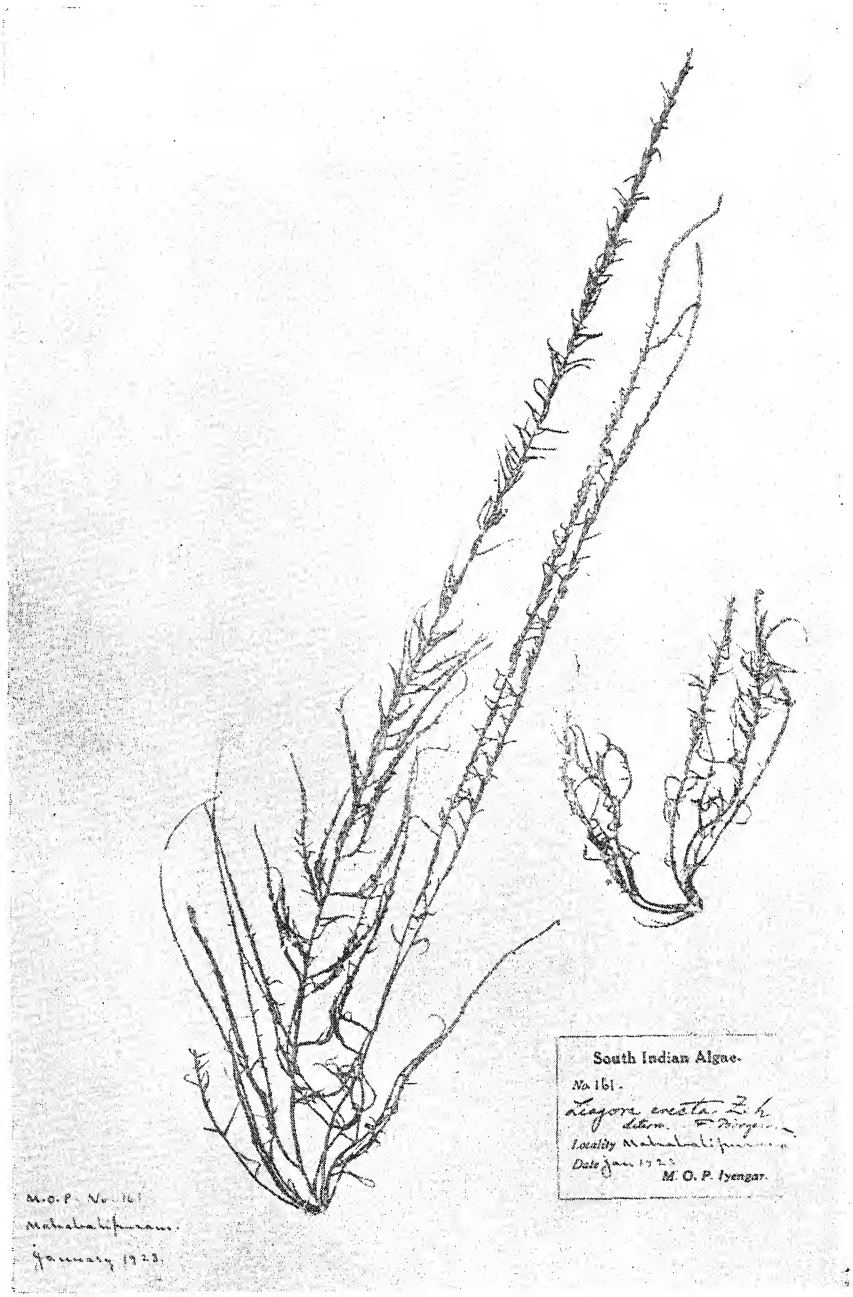


Fig. 33. *Polysiphonia unguiformis* nov. sp. An antheridial stand. × 500.

Explanation of Plate I

Liagora erecta Zeh A male plant to the left and a smaller female one to the right. The male plant is 40 cm. high.


South Indian Algae.
No. 161.
Liagora erecta Zeh.
determ. F. Børgesen
Locality Mahabalipuram
Date Jan. 1923
M. O. P. Iyengar.
M.O.P. No. 161
Mahabalipuram.
January 1923.

F. BOERGESEN—*LIAGORA ERECTA* ZEH.

TWO NEW FLOWERING PLANTS

BY

K. Biswas

Royal Botanic Gardens, Calcutta

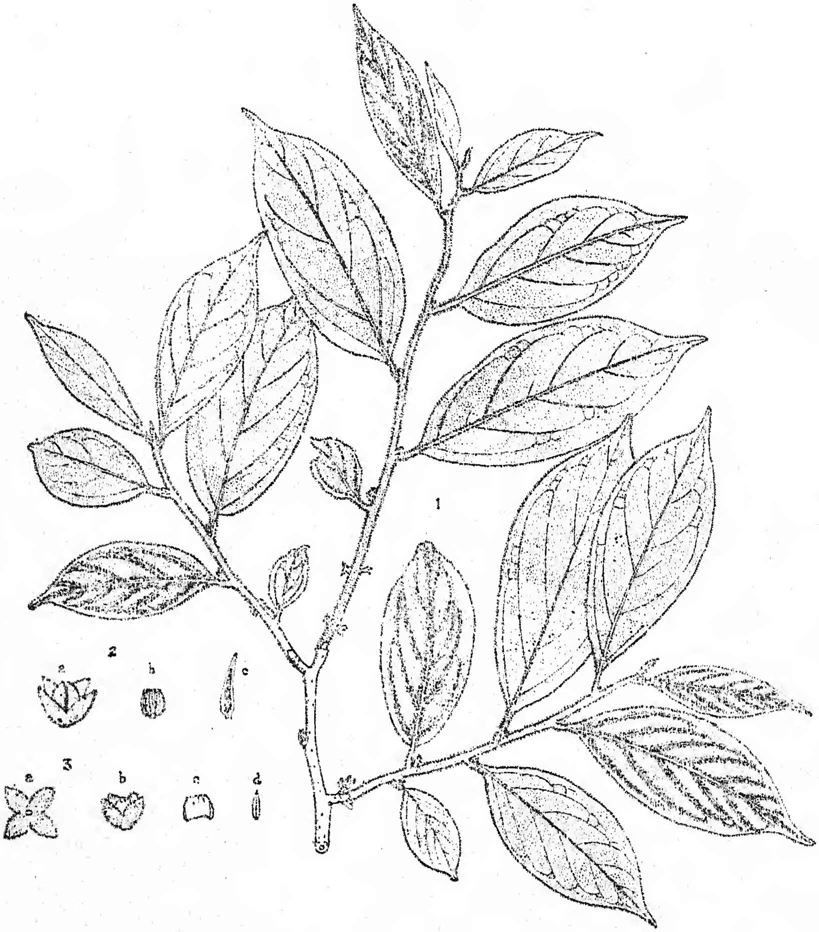
Received for publication on 1st June 1936

The two new species described here are the results of careful scrutiny of the herbarium sheets. Discovery of such new species buried in the thousands of sheets of this herbarium is not of rare occurrence. Workers while examining herbarium sheets discover sheets that cannot be matched and are supposed to be new. After prolonged investigation here and, whenever necessary, subsequent confirmation by the authorities at Kew such sheets are taken as new species. Such a conclusion is also based on valuable materials and whenever possible checked by field investigation. The late Mr. Debbarman discovered these two species and after confirmation at Kew took them as new to science. The writer arrived at the same conclusion after re-investigation. Publication of the descriptions of the species is long overdue. The delay is due to searching out these specimens which were stored aside after the untimely death of the late Mr. Debbarman in 1925. The credit of the discovery of these two new species described is due mainly to the laborious worker, the late Mr. P. M. Debbarman.

Diospyros kika Debbarman et Biswas sp. nov. Ebenaceæ (Text figs. 1-3) species D. Kaki L. f affinis, sed ramis tenuibus et floribus angustioribus ovato vel elliptico-lanceolatis apice obtuse vel sub-caudate acuminatis basibus latioribus distincta.

Arbor. innovationes et inflorescentiæ fulvo-villosæ vel tomentosæ. Cortix coriaceus, striatus. Rami alterni, tenues, teretes, glabri, parce lenticellati; gammae laterales ad ramulorum basin in utraque parte singuli, suamis minutis coriaceis ovatis concavis glabrescentibus obyectae. Folia alterna; lamina 3-8 cm. longa, 1·5-3·5 cm. lata, margine integro et sub-ciliato, sub-coriacea, ovato-vel elliptio-lanceolata, apice subcaudate vel breviter acuminato, basi obtusa vel rotundate, supra fulvo-pubescens et infra tomentosa, demun utrinque subglabra; costa media supra obscura, infra sub-conspicua; nervi laterales in costae mediae utraque parte 4-6; petiolus tenuis, 4-8 mm. longus. Inflorescentiae cyma axillares simplices parvae; pedunculi 3 mm. longi; bracteae 2-3 mm. longae, anguste oval-lanceolatae. Cymæ-3-floriferi, circa 8 mm. longi. Flores (in alabastro) minuti,

rotundatu; pedicelli circa 1 mm. longi. Calyx cirma 3 mm. in longo et dia., 4-fidus; tubus brevisimus; semgenti circa 2 mm. in longo et diam., ovato-acuti. Corolla 2 mm. longa, urceolata, 4-lobata; tubus brevis; lobi contorti, 5 mm. longi, 1 mm. lati, ovati, apice obtuso, extus prope apicem tomentosi, intus glabri. Stamina 20-22; antherae 2-cellatae, linearo-vel ovato-lanceolatae, leviter falcate, subsessiles, connectiva in dorso plus minus pilosa. Pistillodium inconspicuum vel. O. Flores et fructus haud visi.



Text figs. 1-3. Diospyros kika

Fig. 1. A flowering twig; Fig. 2(a). A flower bud; (b) bundle of anthers; (c) dorsal side of an anther enlarged all; Fig. 3 (a) dorsal view of calyx lobes; (b) An unopened flower; (c) Corolla lobes.; (d) ventral side of an anther.

Habitat:—Assam, Manipur, Neung Shong Khong, 1-1300 m., Apr. 1882, G. Watt, No. 6264; Khasia Hills, Nongkhlow, 1450 m. 10th Apr. 1914, U. N. Kanjilal, No. 6706.

Burma, Poneshee, 27th Mar. 1868, D. J. Anderson, No. nil; Pegu, Killoh to Savadhoh, S. Kurz. No. 1008 (Date of collection not known.)

Notes:—The old sheets quoted above were found to have been indifferently referred to either *Diospyros elegans* Clarke or *D. mollis* Griff.; e.g. Watt's No. 6264 from Manipur was found under the cover for the former species, while the Burma specimens collected by Anderson and Kurz were under the cover for the latter species. But these can be readily distinguished from the former species by their shaggy branches and smaller leaves with broadly roundish base and 3-flowered short-peduncled simple cymes of male flowers; and from the latter species by their striated bark and ovate-lanceolate leaves with sub-caudately or shortly acuminate apex.

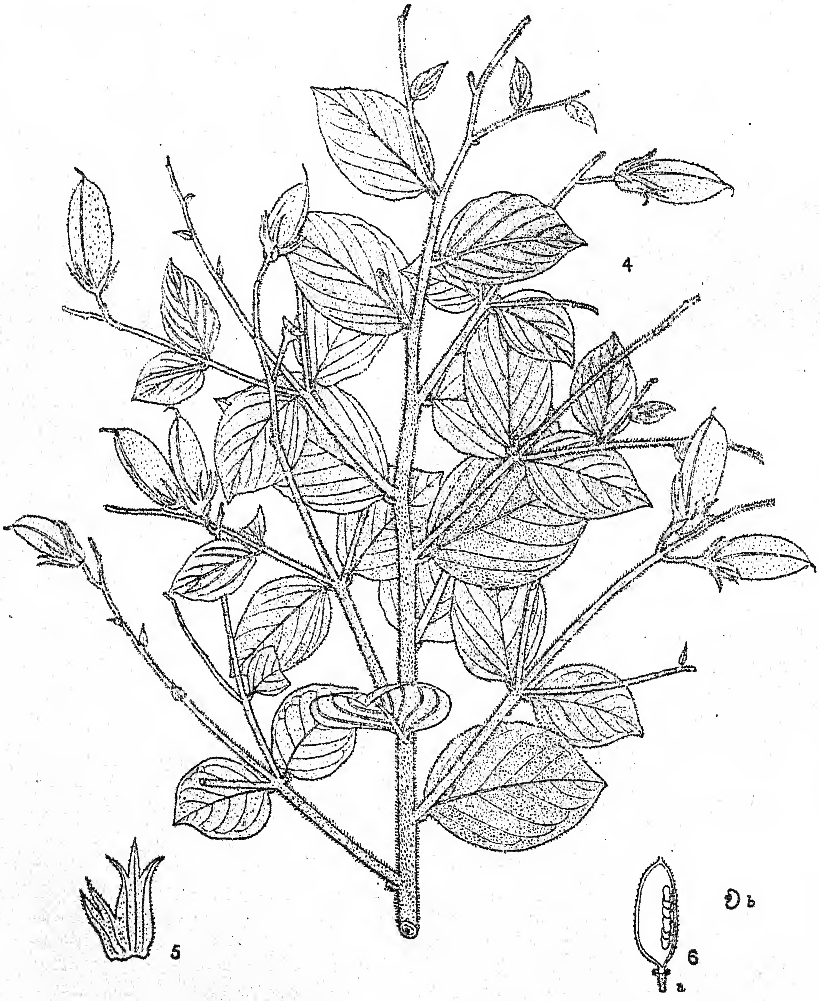
The late Mr. S. T. Dunn, the Assistant for India at Kew, who kindly compared Watt's No. 6264 with the authentic material of *D. elegans* Cl. there, remarked as follows:—" Brandis has examined this number and considered that it represented a new species. The other specimens quoted above agree fairly well with Watt's No. 6264.

It has been given the specific name 'kika' to indicate its affinity with D. kaki L.f.

Crotalaria kodaiensis Debbarman et Biswas sp. nov (Text figs. 4-6) (Leguminosae Genisteæ.) species *C. madurensis* Wight et *C. candicans* Wt. et Arn. affinis sed altera foliorum apicibus late ovato-acutis et basibus breviter rotundatis et altera ramulis fulvo-hirsutis bracteolarum et calycis lobi margine haud revoluto distincta.

Suffrutex multi-ramosus. Innovationes et inflorascentieae dense fulvo-sericeae. Ramie alterni; ramuli oppositi vel sub-oppositi. Folia simplicia, infera alterna, supera fere opposita, sub-sessilia; lamina 2·5-6 cm. longa, 1·5-3·5 cm. lata, integra, sub-coriacea, late ovata apice acuto, basi rotundata, utrinque obscure reticulata et densiter crassiter adpresse sericea; costa media infra conspicua; nervi laterales in costae medicae utraque parte 7-12, infra conspicui; petiolus 0·5-3 mm. longus. Stipulæ O. Inflorescentia paniculata; racemi 6-12 cm. longi; bractae alternantes, margine haud revoluto, 5 mm. longae, 3 mm. latae, sub-coreaceae, ovato-acutae, in sicco supra nigro-brunneæ, subdeciduae; bracteolae 2, oppositae, calycem subtendentes, 4 mm. longae, 2 mm. latae, ovato-lanceolatae, persistentes. Calyx campanulatus, extus hirsutus, intus ingro-fulvus et glaber, persistens, profunde bilabiatus; tubus 2-3 mm. longus, 5 mm. latus;

lobi 5, 3-6 mm. longi, margine haud revoluto, lanceolati vel trianguli. Corolla haud visa, stamena 10, monadelphia, filamentis pilosis; antherae haud visae. Legumen 2·5-3·5 cm. longum, 1-1·25 cm. crassum, rectum, oblongum, densiter adpresse sericeum; pedicelli fructiferi 0·7-1 cm. longi, oppositi; styli 5-6 mm. longi, tenues, curvati, barbari; stigma minutum, obliqu-



Text figs. 4-6. Crotalaria kodaiensis

Fig. 4. A flowering twig; Fig. 5. Calyx tube opened out showing erect nature of the margin of the calyx lobes; Fig. 6 (a). Longitudinal section of legume with some of the ovules in tact; (b) a seed.

um, subglabrum; semina 10-12, 3-3·5 mm. longa, 2-2·5 lata, reniformia; testa nigra, nitida, glabra.

Habitat:—Madras Presidency, Kodaikanal Hills, Topon (Tope), 360 m., Jan. 1916. C. Tomtand, No. 1605.

This new species, although based on the fruiting specimens can readily be distinguished by the characteristic bracteoles on the smaller twigs and non-revolute margins of calyx lobes.

THE RÔLE OF LEAF WATER-CONTENT, SOIL MOISTURE AND PLANT AGE ON TRANSPIRATION OF CROP PLANTS

By
B. N. Singh, D.Sc.
AND
R. B. Singh, M.Sc.

Introduction

In a preceding communication (1) a detailed study was made of the amount of water required by the crops for irrigation and the critical periods when they have need for maximum and minimum water supply. In any study directed to evolving drought-resistant and flood-resistant varieties, a study of the relation of external as well as the internal factors to transpiration is thus both imperative and important.

The present contribution aims at investigating the relation of leaf-water-content, soil-moisture, and plant-age to transpiration under natural conditions of environment and their relative efficiency in regulating the transpirational loss of water from plants.

Three important crops of agricultural interest and value, representatives of three agro-biologic groups, namely, cotton (*var.* Cawnpore 520), an apparently low water requiring crop; tobacco (*var.* Pusa 177), a summer crop with high water requirement; and rice (*var.* Kasturi) a rainy season crop yet having a high water requirement, are selected for experimentation.

Method

The general procedure of work in the present investigation consisted in the periodical determination of transpirational loss of water at different stages of plant growth on representative days of the season. An idea of the environic complex and the evaporating power of the atmosphere on such days was obtained by noting the changes which each one of the factors undergo from hour to hour as also by measuring the amount of water lost during evaporation from a shallow water pan. A detailed discussion of the method adopted has been given elsewhere (6). A brief outline is, however, given below.

Determination of transpiration: In practically all the previous studies conducted on potted plants, the size of the pots has been a serious handicap in the way of getting correct figures of water loss from plants. Thus a reduction in the size of the pots and the soil nutrients contained in it leads to restricted growth of the roots affecting thereby the size of the plant, and an increase in the size of the pots to allow full growth and development of the roots (cf. Briggs and Shantz) would mean weighing the water loss on larger balances where accuracy in the weight of the water loss is to be doubted. This led to a critical study at this Experiment Station and the following method gave satisfactory results.

The plants were raised in pots from the very start of their life-cycle. To ensure homogeneous growth under as natural conditions as possible, as also under optimum conditions of nutrition, the pots were buried to the extent of three-fourths of the size in trenches alternating with the plants grown directly into the fields. This method decreased the size of the pots considerably without affecting growth in the least and thus decreased the percentage of error in weighing the pots. The pots were encased in metal containers, fitted tight with the two halves of metal cover and hermetically sealed a the perforations. To allow the loss of water only through leaves, the other parts of the plants were coated with wax mixture. For keeping down the temperature of the roots which are most susceptible to high temperature influence, the metal containers were next placed in specially prepared wooden air incubators described elsewhere (6) and left in the open.

The transpiration for six plants was measured and determined individually per thousand square centimeters in order to provide a basis for the calculation of the probable error of the mean. The data thus have been statistically tested with regard to their significance and only the average of such six readings is shown in the figures.

Evaporation measurement: For measuring evaporation various methods have been in use at this Experiment Station (6) and it has been inferred that evaporation from shallow pan approximates more near the evaporating power of the leaf than from any other. This led to the selection of a shallow water copper pan of 31 cm diameter and 3 inches depth for determining evaporation. The pan is filled upto a depth of 2.8 inches, weighed at regular intervals and arranged on a table side by side with the experimental plants in the open. The loss of water at successive time intervals during the periods of observation was noted and an equivalent amount added each time to make good the loss and maintain the same depth of water in the pan.

Meteorological records: Regular records of atmospheric temperature, humidity, wind velocity, sunshine and sky conditions, were simultaneously kept for evaluating the extent to which the intensity of environmental factors singly or jointly affect both evaporation and transpiration.

Leaf area: Immediately after the determination of fresh weight of the leaves, the area of the leaf was traced on the paper and the leaves subsequently transferred to the air incubator controlled at 100°C. The area was finally determined by means of planimeter and was doubled to get the area exposed by both the surfaces of the leaves. Loss of water both due to evaporation and transpiration was reduced to unit area.

Determination of leaf water-content: The experience has shown that even the slightest carelessness in determining the water-content of leaves is apt to yield wrong results and thus give an entirely untrue picture as to the relation of water-content to transpiration. Great care was, therefore, exercised in collecting representative types of the experimental leaves from plants of the same age and possessing similar characteristics and at once transferring them to an air-tight wide mouthed correctly weighed weight-bottle to avoid any loss of water due to transpiration during experimentation. The difference between the original and final weight of the weight-bottle gives the fresh weight of the leaves. The dry weight was determined by repeated desiccation in an incubator at 98—100° C till a constant weight was obtained. The moisture content was then calculated to unit area of leaves.

Soil moisture: To maintain a definite grade of soil moisture, the pot and the soil in it were weighed separately and the percentage of moisture in the soil determined. The plant is fixed in it and the required soil-moisture was kept up by adding water to it every day in the morning after weighing.

Data and Discussion

Transpiration in relation to a daily maximum evaporation.

On critically examining the values of transpiration and evaporation got on clear days in relation to varying evaporating conditions of the atmosphere for any one crop and at any particular stage in life-cycle, it is observed that with an increase in evaporation and the intensity of atmospheric conditions, the general trend of the transpiration curve is to rise and follow that of the evaporation upto a certain limit of atmospheric conditions. The optimal value of evaporation having been reached, further increase in either evaporation or the intensity of evaporating conditions, seems to have little relation with the transpiration curve which at first shows a rounding off and later attains a level phase so characteristic of a limiting factor curve (Fig. 1).

Thus the general conclusion is arrived at that on different days during a particular developmental stage, no appreciable variation is noticed in the daily average rates of transpiration, howsoever severe the evaporating conditions may become. It appears that transpiration is limited to a daily maximum loss of water, the obvious importance of such a regulation amidst changing yet severe environmental complex, being to check the useless loss of water from the plant in order to cut short the water requirement of crops and to subsequently reduce the number of irrigations to a necessary minimum.

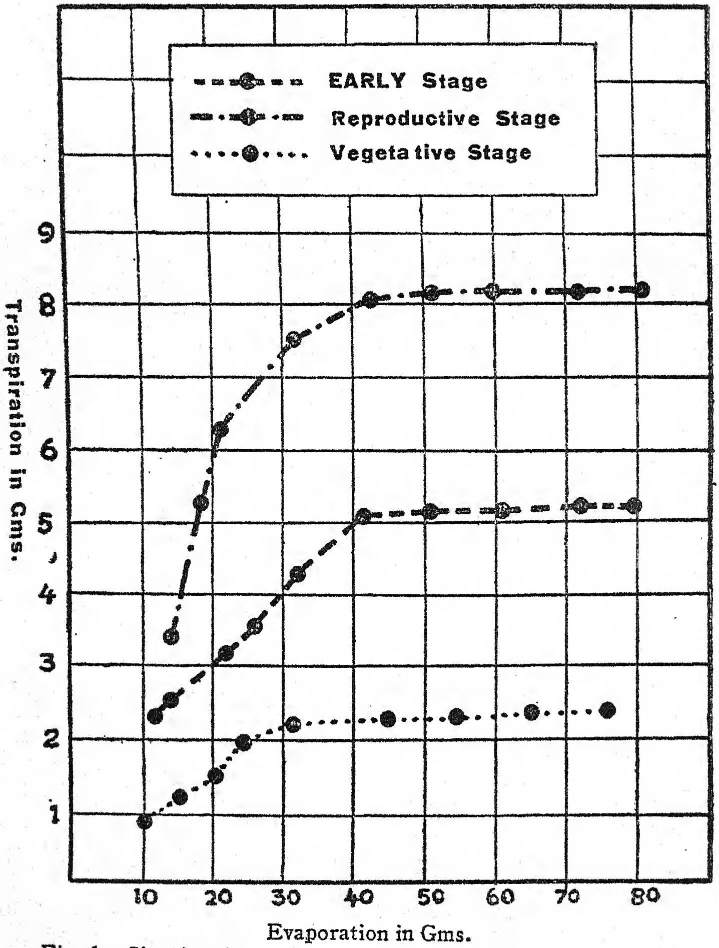


Fig. 1.—Showing the effect of evaporation on Transpiration at different tages of growth of Cotton plant.

Relation between environmental factors and transpiration.

Previous work (6) conducted at this Experimental Station has led to the conclusion that on clear days, the more important external factors that are observed to affect transpiration in these regions are temperature, humidity and wind velocity.

The rate of transpiration generally begins to rise with the increase in the intensity of these factors in the morning and reaches its maximum somewhere between 10 A.M. and 2 P.M. The maxima of transpiration and any one of the individual environmental factors may sometimes coincide, but to be sure, they are generally held at different times. Due to lack of space a single yet typical instance is cited (Fig. II) where the maximum of temperature coincides with that of transpiration while the minimum of humidity is held an hour later than the maximum of transpiration but begins to decline in advance of the latter. This is the general behaviour of the environmental factors when taken in conjunction with the transpirational

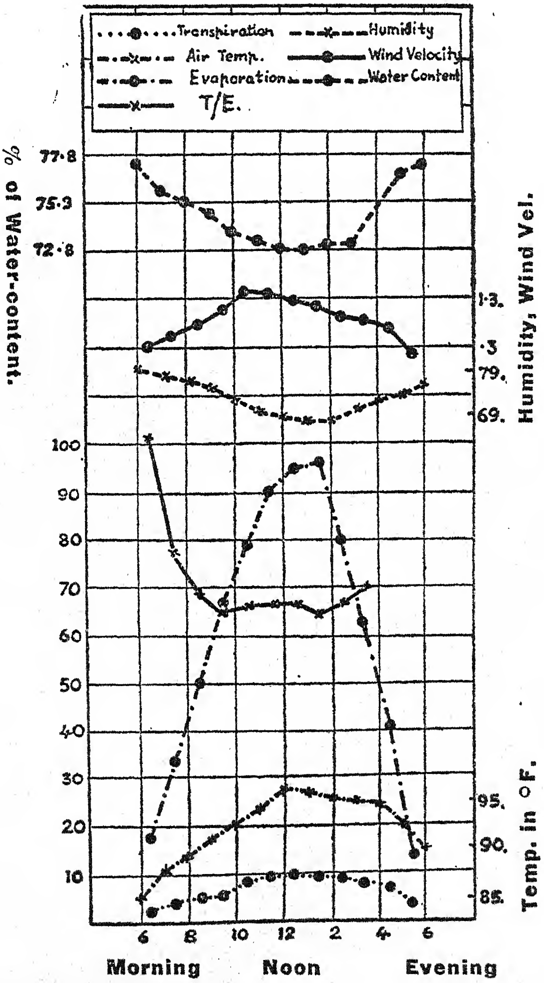


Fig. 2.—Showing the march of atmospheric variables on a single day.

changes in all the three crops at practically every stage of development.

Due to the varying influence of all these factors on transpiration it seems difficult to study the relation between the external factors and transpiration unless the combined influence of these factors is expressed in terms of the evaporation-power of the air.

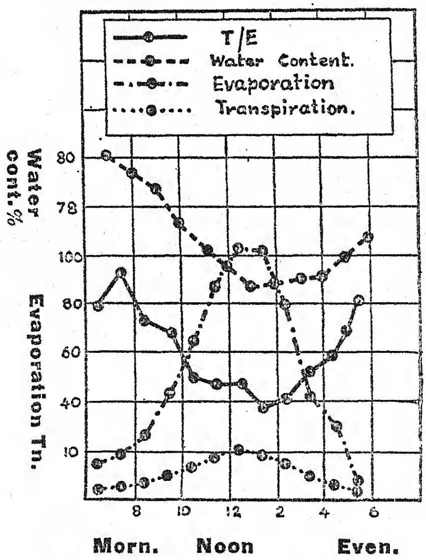


Fig. 3.—Showing march of relative Transpiration and moisture content of Cotton leaf on a hot day. (18th August.)

Transpiration and Evaporation relationship.

Both transpiration and evaporation (Figs. II and III) begin to rise from the early morning and reach their maxima somewhere between 10 A.M. and 2 P.M. Either the maxima of both are held at the same time or transpiration reaches its climax earlier than evaporation. The latter may be explained on the basis of the fact that the rate of transpiration is checked by some internal factor before the atmospheric conditions reach their highest severity and as such, may be taken to be somewhat independent of evaporating conditions of the atmosphere at least when conditions become severe.

Operation of internal factors as revealed by relative transpiration study.

In order to study the physiological behaviour of the leaf, elimination of the evaporating power of the air is effected by computing the values in terms of relative transpiration. A reference to Fig. 2 reveals that the relative transpiration declines from the early morning till 1 or 2 P.M. and with the approach of evening subsequently rises. The fall in relative transpiration may be ascribed to a check of transpiration and when the check is released the relative transpiration goes on rising upto evening. If both transpiration and evaporation were affected to the same extent, the curve should be a straight line. The results of experimentation, however, show that transpiration is increasing less rapidly than evaporation till the maximum is reached and the subsequent increase in the evaporating power of the air is not reflected in transpiration, possibly due to the controlling influence on it of some internal factor.

Consideration of internal factors controlling transpiration.

The mechanism for the control of transpiration in plants is rather complex and has given rise to the investigation into the internal factors which chiefly help in its regulation. A consideration of the more important internal factors, at least those for which we have some experimental back-ground, is to be made in this sub-section.

Contribution of stomata in the regulation of transpiration: The earlier scientists held the view that transpiration is greatly regulated by changes of stomatal aperture. Darwin (1) has shown that a direct relationship exists between transpiration and stomatal opening. This theory was criticised vigorously by Lloyd (5) who could point out that stomata are not closely regulatory of the loss of water from the leaf and that there is a close relation between the fall in the moisture-content of leaves and the increase in the rate of transpiration (5). Livingston and Brown put forward the hypothesis that incipient or partial drying of exposed membranes regulates transpiration (4). Knight pointed out that water-content of leaves is more responsible for the control of transpiration than stomatal movement (2 and 3). In the light of the above, it may thus be remarked that stomata is probably not an important factor governing transpiration. The state of hydration is considered to have greater control over the process.

In order to examine in detail the relationship of transpiration to stomatal number, the wet-wall area, the pore-diameter, the pore-area, the height of the stomatal neck and such other details, a separate series of experiments are undertaken (10). The results show no significant relationship between the stomatal characteristics and transpiration.

To test whether transpiration in the present investigation is in any way governed by water-content, a series of experiments were conducted.

The rôle of leaf water-content in the control of transpiration.

The hourly march of water-content of leaves stands opposite to the course of both transpiration and evaporation. It begins to fall with the rise of transpiration and reaches its minimum soon after the maximum of the latter, after which it rises again over night and continues to do so till 6 A.M. the next morning. If relative transpiration is compared with that of the water-content of leaves, a direct relationship is found to hold between the two (Fig. 3). The fall in the relative transpiration at a time when evaporation increases, thus points to the operation of an internal factor imposing a check upon transpiration. The more is the check operative, the greater is the fall in the water-content of leaves. It follows therefore that the water content of leaves is related to the control of transpiration.

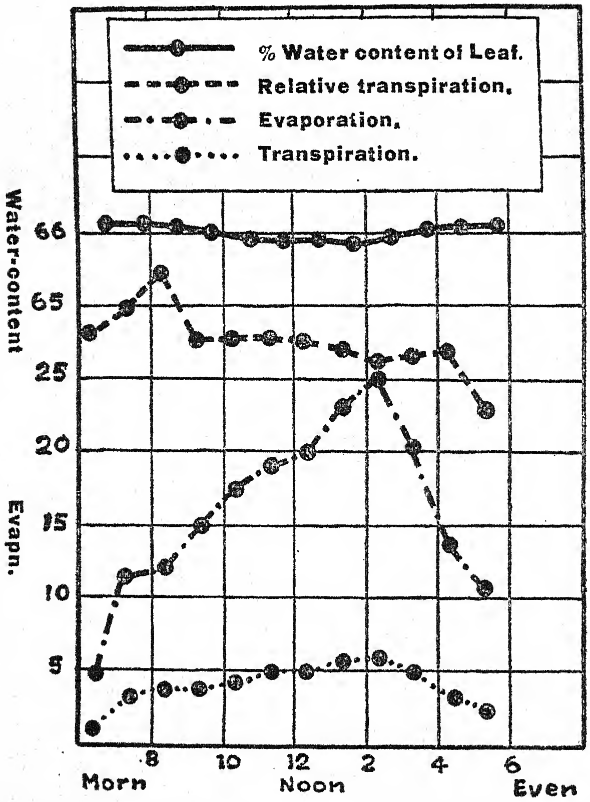


Fig. 4.—Showing the march of relative transpiration and water-content in rice on a humid and cloudy day. (21st September.)

On cloudy and humid days the hourly march of relative transpiration fails to indicate any appreciable decrease in the day as noted on clear days. This shows that transpiration is retarded more or less proportionately to evaporation on such days. However, when we turn our attention to examining the water-content of leaves, we fail to notice any marked fall during the hours of the day indicating thereby its correlation with the curves of T/E ratio.

On very hot days, however, (Fig. II) the relative transpiration begins to fall from the early morning hours, showing thereby that the value of evaporation is in excess of transpiration, and therefore one may infer that transpiration is relatively independent of evaporation or, in other words, the influence of atmospheric factor leading to the view that the control of transpiration is brought about by some other internal factor. The water-content of leaves also falls wih the value of relative transpiration upto noon and rises with it towards the evening, emphasising thereby a correlation between the two.

On the strength of the foregoing discussion, it may appear that the water-content of leaves is the controlling factor for transpiration as indeed supported by the views of many workers in the field.

In view of experimental findings, however, we have certain difficulties in our way of accepting the above view and without unnecessarily going into their details we give the data below.

TABLE I

Moisture content of leaves in different stages of life-cycle

Age of plants in days.	Developmental stage.	% of moisture content of leaves	Diff. between max. & mim. water content of leaves in the day.	Remarks.
		COTTON.		
10	Seedling stage	79.84	4.90	Expt. conducted on the same day (Sept. 20th clear day).
36	Vegetative stage	77.46	3.92	
75	Flowering stage	75.45	3.33	
		RICE.		
16	Seedling stage	91.85	4.65	March 26th clear day.
46	Vegetative stage	90 24	3.97	
102	Flowering stage	83.42	3.41	

(i) From a review of Table I it will be made out that the higher the percentage of water-content in the leaves, the greater is the difference between their maximum and minimum water-content. As the age of the plant increases the water-content of leaves becomes less and less. During the seedling stage, the water-content of leaves is the highest, it becomes lower during vegetative period and is the lowest during pre-flowering and flowering periods. If the water-content of leaves is taken as the only controlling factor for transpiration, during flowering period transpiration should be lower than that during the vegetative or seedling stages which maintain higher water-content of leaves (Fig. I).

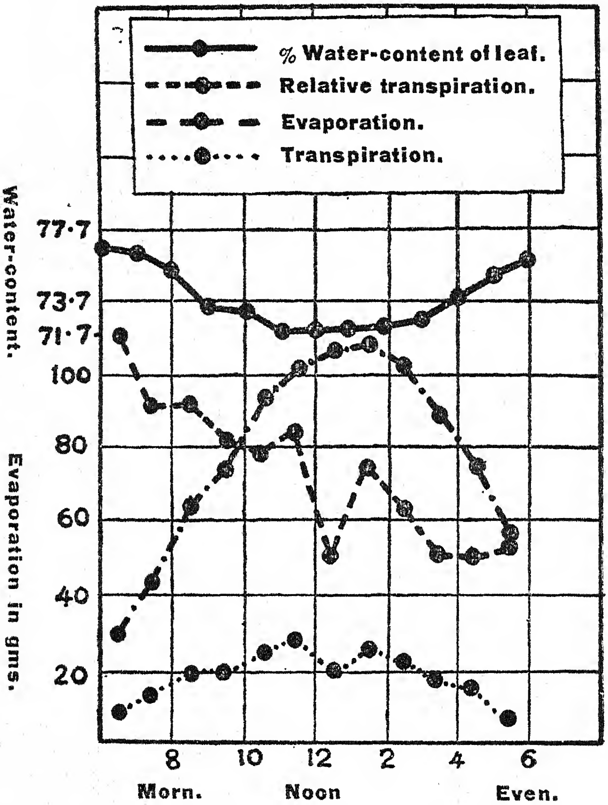


Fig. 5. Showing relationship of transpiration to water-content in cotton leaf on a very hot day (29th October).

(ii) Transpiration/evaporation ratio is not always accompanied by a fall in the water-content. Once the evaporation reaches a maximum, the water-content begins to rise at a time when the relative transpiration shows a continuous decline, it seems, therefore, that some factor other than the water-content of leaves probably determines the control of transpiration under such a state of affairs.

(iii) The rate of transpiration does not seem to have a definite gradation from crop to crop according to the water-content of leaves. The highest daily transpiration rate is observed in rice which has the least water-content when compared with either cotton or tobacco. Cotton has the lowest transpiration rate but the water-content is highest. This irregularity in the proportionality between the rate of transpiration and water-content of leaves goes again to indicate the presence of some internal factor other than this, which is common to all the crops and controls transpiration.

TABLE II

Transpiration rate for plants of various ages

Crop.	Age of plant in days.	Percentage of moisture content of leaves*	Name of the stage of crop.	Transpiration in gms. per 1,000 sq. cm. per day of 12 hours.	Remarks.
Cotton.	5	80.24	Seedling stage	65.021	Experiment carried out on the 12th Sept. 1932 which was a clear day.
	39	77.56	Vegetative stage	29.520	
	72	75.12	Preflowering stage.	96.870	
Rice.	10	68.24	Seedling stage	98.316	Experiment carried out on the 26th Sept. 1932 which was a clear day.
	42	65.75	Vegetative stage	39.456	
	65	63.86	Preflowering stage.	152.321	
Tobacco.	12	92.05	Seedling stage	93.512	Experiment carried out on the 26th March 1932 which was a quite hot and windy day.
	41	90.12	Vegetative stage	24.582	
	98	84.52	Preflowering stage.	97.321	

* Moisture content of leaves taken at 6 a.m. always.

(iv) There is no definite water-content of leaves at which the relative transpiration goes down or transpiration retarded. Sometimes the relative transpiration begins to fall at higher water-content of leaves than at others (Figs. II, III, and IV). This emphasises again that check of transpiration is not imposed by the water-content of leaves but some other internal factors.

(v) Again, with reference to Fig. VI which gives account of transpiration on a cloudy and humid day, it may be observed that the relative transpiration shows a progressive rise at least upto the noon, indicating thereby that transpiration is positively in advance of evaporation. The curve of water-content of leaves for the same period, on the contrary, shows a fall and does not, as expected, seem to hold any relation with the control of transpiration.

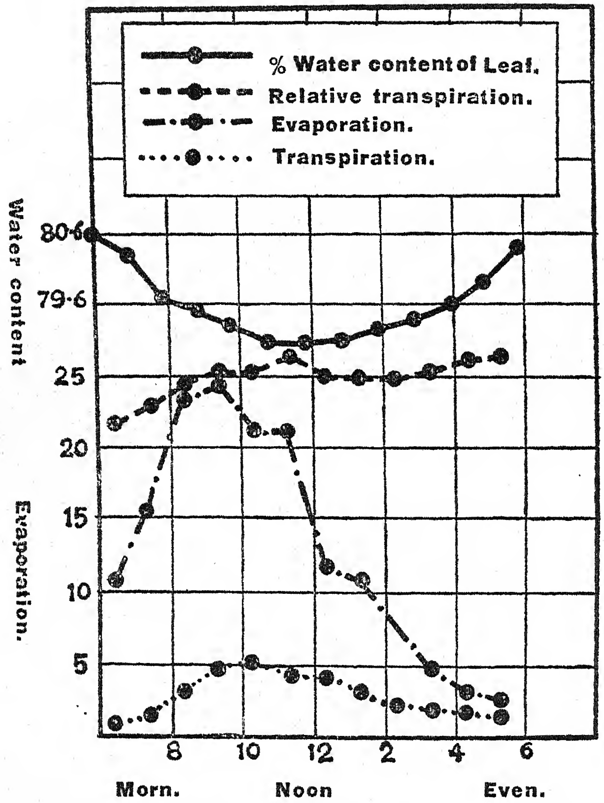


Fig. 6.—Showing the march of relative transpiration and water content in cotton on a very humid day (14th August).

These facts do not seem to lend support to the idea of water-content of leaves being the dominant factor in the control of transpiration.

The average hourly rate of transpiration is highest (Table II) during the seedling and pre-flowering periods of a crop when the metabolic processes are also most vigorous, and lowest during the vegetative period of slow metabolism. In a parallel but separate investigation from this Agricultural Experiment Station it has been shown that during the periods of high metabolism, the absorption of nutrient solutions is increased to a great extent (8). This points to the idea of relationship between transpiration and absorption from the soil and would require experimental proof in order to come to any definite conclusion.

Soil moisture and transpiration relationship.

When we proceed theoretically to trace the cause of the fall in water-content of leaves when transpiration rises, we are at once reminded of the supply of water from the soil to the transpiring leaves. The power of plants to take water from the soil is limited. When transpiration is high, water cannot naturally be supplied at the same rate by the roots and following this misfit, the water-content of leaves falls. Thus the need for finding out the limit of resistance offered by the plant for transpiration due to the deficiency of water supply to roots becomes obvious.

Experiments are planned in which the amount of water supply to the soil is varied in case of different plants and the varying degrees of response due to this are noted on transpiration to seek the relation between the two. Three sets of cotton and rice plants of the same age are maintained at different percentages of water-content of soil. In cotton the water-content of the soil is maintained at 20 per cent., 16 per cent., and 11 per cent. In the case of rice it is kept at 29 per cent., 21 per cent., and 10 per cent. The same grades are maintained in parallel sets for finding out the water-content of leaves simultaneously. Evaporation and other meteorological records are kept from hour to hour as usual. A detailed study as to the influence of soil moisture on the transpiration and water requirement of both cereal and vegetable crops made in a separate paper (11) goes to support these results.

On examining the experimental data (Table III) it is seen that there is a close relationship between the average hourly rate of transpiration and the water-content of the soil. It is found that a high rate of transpiration is directly proportional to the high water-content in the soil.

If the water-content of leaves is taken as the only controlling factor for transpiration, it ought to maintain its minimum value reached in the normal plants by decreasing transpiration. On the contrary, it is found that in the case of water-deficiency, the leaves lose water much below that in the normal ones. It thus shows that water-content of leaves does not to any remarkable degree take part in maintaining its value by decreasing the rate of transpiration but is probably the balance between the rate of transpiration and that of absorption.

These experiments go to show that soil moisture may determine the rate of transpiration more than water-content of leaves and thus might control the loss of water during transpiration to a greater extent.

Age factor in relation to transpiration.

The high water requirement shown by the crops during the critical periods, *i.e.*, the seedling and preflowering stages (9) stresses the importance of age of a plant in determining the rate

TABLE III

Effect of different moisture content in soil on transpiration and moisture content of leaves

Period.	Av. amount of Tn. per 1000 sq. cm. per hour.			Dif. between the max. & min. water cont. of leaf in day.			REMARKS.
	20% moisture content in soil.	16% moisture content in soil.	11% moisture content in soil.	20% moisture content in soil.	16% moisture content in soil.	11% moisture content in soil.	
				COTTON			
23rd Oct. 6 A.M.—6 P.M.	7.53	6.74	4.758	4.70	6.86	9.71	Clear sky and flowering period.
				RICE			
	29% moist. in soil.	21% moist. in soil.	10% moist. in soil.	29% moist. in soil	21% moist. in soil	10% moist. in soil	
26th Oct. 6 A.M.—6 P.M.	13.34	7.33	4.639	5.4	7.37	8.65	Flowering plant clear sky.

of transpiration and thus needs an attempt to the investigation of a new factor not recognised so far in the regulation of transpiration.

Experiments are conducted with plants of varying age and developmental stage of the crop, on the same day and under the same environments.

The experimental data (Table II) go to show that the average daily rate of transpiration for a particular crop varies in accordance with the metabolic need of the plant at different developmental stages in the life-cycle of each crop. The experimental plants have lowest amount of transpiration during vegetative stage and highest during the seedling and the stage prior to the initiation of reproductive primordia, emphasising thereby the specific need for irrigation during these stages of high transpiration, but the variation of hourly rate of transpiration from age to age under more or less similar environmental conditions goes to prove the control of age on transpiration. Further, the stages of high average rate of transpiration represent periods of high metabolism when absorption is high, thus indicating the indirect effect of absorption on transpiration whereas the direct influence has already been shown and discussed in the previous pages.

Relative physiological resistance of crops to transpiration.

In order to study the physiological resistance offered by different kinds of crops to transpiration and the march of the water-content of leaves in them, experiments are conducted with rice and cotton plants on the same day and under the same environmental conditions. The plants are sealed properly and weighed for transpiration. The water-content of leaves is found in the same way as before. Evaporation and other meteorological observations are taken simultaneously.

When hourly march of transpiration for rice is compared to that of cotton (Fig. 7) it is noticed that while no depression occurs in the transpiration rate of the former, that for the latter fall suddenly between 11 A.M. and 12 noon and rises again. The cotton plant seems to afford more resistance to the evaporating power of atmosphere and as a result of it there occurs a misfit in the two resulting in a depression in the case of cotton. When attention is directed towards the water-content of leaves of these two kinds of plants, it is seen that in the case of cotton it keeps constant between 11 A.M. and 2 P.M. even when evaporation goes high and does not seem to have any relation with the depression in transpiration.

This strengthens the view put forward previously that transpiration is to a large extent determined by absorption and gives a clue to the effect that water-content of leaves may not be responsible for the depression in transpiration in the early hours.

This fact shows that cotton resists the loss of water more than rice under the same environmental conditions and does not allow transpiration to go much in advance of evaporation as proved by the constancy in the water-content of leaves.

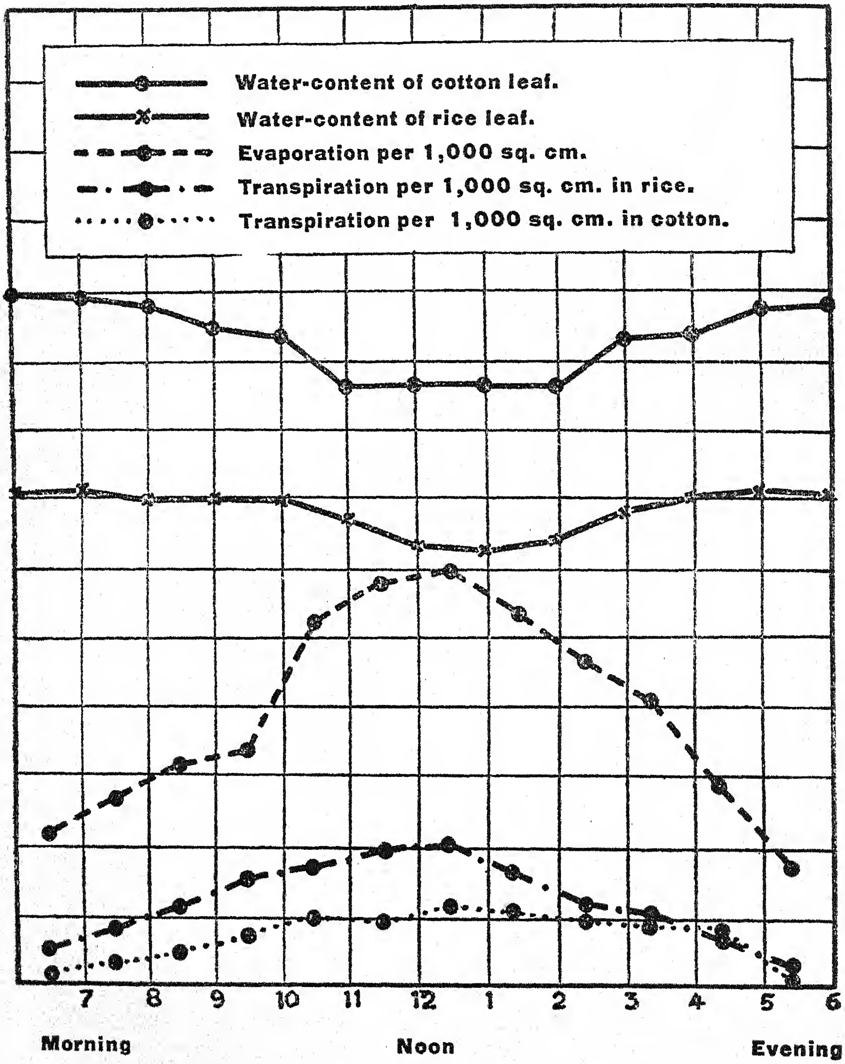


Fig. 7.—Showing the relation between transpiration and water-content of leaf of cotton and rice.

There is also a great deal of variation between the average hourly values of transpiration of these two groups. Rice transpires 13.21 gms. and cotton 8.01 gms. per hour per 1,000 sq. cms.

Summary and Conclusion

The present paper deals with transpiration of crop plants in relation to environmental complex and other internal factors. A study is made of transpiration/evaporation, water-content of leaves, soil moisture and age relationship to transpiration.

An analysis and discussion of the data lead to the following conclusions:—

For a given crop no appreciable difference is to be noted in the daily rates of transpiration at a particular stage of development (seedling, vegetative or reproductive) in spite of the change in the evaporating power of the atmosphere. Such a regulation in the daily loss of water amidst changing environmental complex probably goes a long way to economise the water requirement of crops and cuts down the number of irrigations to a necessary minimum.

The average daily rate of transpiration for a particular crop varies in accordance with the metabolic need of the plant at different developmental stages in the life-cycle of each crop. The experimental crops have high hourly rate of transpiration during the seedling stage and the stage prior to the initiation of reproductive primordia, emphasising thereby the specific need for irrigation during these stages.

The view is held that the water-content of leaves represents the balance between absorption on the one hand, and transpiration on the other. If transpiration is in advance of absorption a deficit in the water-content should follow, but when reverse is the case the water-content should result in an increase. This explains the inverse behaviour of the rate of transpiration and the water-content of leaves. The experiments on the varying doses of water supply in rice and cotton go to indicate that a high rate of transpiration is directly proportional to high rate of watering—medium watering hence medium absorption leads to medium transpiration, and scanty watering results in low absorption and low transpiration.

The severeness in the intensity of transpiration creates a disturbance in the rate of water supply to the evaporating surface of leaves leading to a forenoon depression in the transpiration rate even when the water-content of leaves keeps constant but evaporation goes on increasing. This strengthens the view put forward above that transpiration is to a large extent determined by absorption and gives a clue to the effect that water-content of leaves may not be responsible for the depression in transpiration in the early hour.

Different crops seem to have got different physiological resisting power for transpiration under similar conditions of environment.

Different crops seem to possess varying daily rate of transpiration per unit area even under similar conditions of atmospheric variables, proving thereby the relevance of one crop requiring more irrigations than another.

The greater the percentage of water-content during the active period of growth, the greater is the difference between the maximum and minimum of the water-content of the day.

The variations in the water-content of leaves becomes less and less as the age of the plant increases or, in other words, with the advent of age the water-content of leaves during the day, approximates to an average minimum from hour to hour on a clear day.

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UNEQUAL ABSORPTION OF IONS AND THEIR RATE AND ORDER OF ENTRY FROM A 3-SALT NUTRIENT*

BY

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AND

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Introduction

Of the many nutritional problems the one which has attracted the greatest attention of the investigators within recent years, is the process of absorption of nutrients by the roots of the living plant. Yet due to the several complexities of the process, the nature of absorption is not fully understood. In investigating the phenomenon of absorption the problems which primarily present themselves are: In what manner does the intake of ions take place? What is the rate at which they are absorbed? and in what order are the ions taken up?

Working with entire plants or separated tissues a number of investigators have observed differential absorption of twin ions of nutrient salts and their interchange with those of others present in plant cells. But on going through the literature (Hass and Reed 1926, Hoagland 1918, Kahho 1921, Meurer 1909, Pantanelli 1915, Redfern 1922, Ruhland 1909, Stiles 1924, Thomas 1930) on the subject, it will be observed that in the majority of cases the experiments have been conducted in single salt culture media consisting of one anion and one kation, and either the anion or the kation has been found to show differential absorption by the plant material. Further, the observations being conducted over short durations, fail to give an idea of the distribution of ions in time and space extending over a wider range of the normal life-cycle of plants.

Single salt solutions, however serviceable they may be from the point of view with which they have been used by earlier workers, have the clear disadvantage of providing an abnormal nutrient medium for a plant which grows better in a completely balanced solution approximating the soil as nearly as possible. It should therefore be interesting to examine whether unequal absorption is due to a pathological condition induced by the unbalanced single salt solution or whether it is a normal feature of plants growing in a complete nutrient as well.

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*Contribution from the Institute of Agricultural Research, Benares Hindu University.

In order to gain a clearer insight into the process, specially along the lines indicated above, pure strains of linseed, wheat, and paddy are grown in a 3-salt solution and study of the quantitative absorption of ions present in the solution at successive stages of growth from germination onwards, undertaken. Simultaneous observations are also made of the change in the pH of the culture medium. In addition to the unequal absorption of ions, the analysis of the data has also been extended to their order and rate of entry.

Experimental

Pure strains of linseed (flax, *var.* Cawnpore 1150), wheat (*var.* Pusa 4) and paddy (*var.* Jilhore) were germinated on a three-inch bed of pure sterilised sand soaked with Shive's (1915) R5 S2 3-salt optimum solution subsequently used as culture medium. Seedlings which have just developed green pigment were carefully transferred to culture vessels of hard resistant glass, the capacity of which varied from 300—4,000 c.c. During the seedling stage the plants, five in number, were grown in culture vessels of smaller size. As the plants grew larger, containers were used with more nutrient, care being taken that at no stage did the cultural solution limit the growth of the plants. Up to the fourth week in the life-cycle of the plants 60 bottles carrying 300 plants were used for experimentation. After this the number of plants used was reduced to 100 on account of the difficulty of handling a large amount of solution for analysis.

Merck's reagent salts were used in the preparation of the solution. The nutrient medium was accurately prepared from previously analysed stock solutions. After the allotted period of absorption the plants were drawn out of the culture solution, their roots thoroughly washed and the entire solution made up to a known volume. From this was estimated the quantity of ions left after absorption.

But for modifications here and there the methods adopted for the estimation of the elements were the ones mentioned in standard works on chemical analysis (Clowes and Coleman, 1918, Treadwell and Hall, 1924). Calcium was estimated gravimetrically after precipitating it by ammonium oxalate in the presence of acetic acid and an excess of ammonium chloride. Acetic acid prevents the precipitation of phosphate and ammonium chloride that of magnesium.

Two separate filtrates from calcium estimation were taken for the estimation of magnesium and phosphate. Magnesium was estimated by the usual pyrophosphate method. Phosphate was estimated by double precipitation with magnesia mixture and weighing the resulting precipitate as magnesium pyrophosphate.

Estimation of sulphate was made from another sample of the solution, by precipitating it with barium chloride in presence of hydrochloric acid. Before use the solution was made completely free from nitrate, by repeated evaporation with concentrated hydrochloric acid. This prevented the precipitation of barium nitrate.

The filtrate from above was used for potassium estimation by the usual perchlorate method. The perchloric acid used was always fresh. Nitrate was estimated in the form of ammonia by reducing it with Devarda's alloy and sodium hydroxide.

All analytical data have been recorded up to the 4th place of decimal. Each estimation has been repeated thrice and no reading has been accepted as correct until and unless the readings of the different estimations differ only in the last decimal place. The amount of ions taken in, has been found out from the difference in their quantity present in the solution before and after absorption. The results which were originally obtained in grams have been reduced to gram equivalent for 100 plants by dividing them with the molecular weights of the elements. Calculations for this have been made generally up to the fourth place of decimal but it had to be extended to the 6th place when the amount of ions absorbed was less.

The determination of hydrogen ions was made by the electrometric method. As the hydrogen electrode could not be used owing to the presence of nitrate (an oxidising substance), quinhydrone electrode was adopted throughout the course of the present investigation. This electrode answered our purpose well. Quinhydrone was prepared after Biilamann (Britton 1932).

The voltage was determined with the help of a saturated calomel electrode, potentiometer and a galvanometer which were supplied by the Cambridge Sci. Inst. Co., and are of the most accurate type available.

Platinum electrode used for the experiment was cleaned with hot chromic acid mixture, washed with distilled water and heated in an alcohol flame. Every possible care was taken to avoid the leakage of mercury through the seal which according to Morgan, Lammert and Campbell (1931) gives rise to an error as high as 0.1 volt. Calculations have been made by taking the quinhydrone electrode as 0.7044 volts positive to the hydrogen electrode as recommended by Britton.

In order to avoid differences due to individual variations a large number of plants ranging from 100—300 are used for each experiment. The solution obtained for analysis thus represented a mean for the total reaction due to a population of plants.

Data and Discussion

The intake of ions from the nutrient at successive stages of growth is determined from the difference of the original concentration of the solution and that obtaining at the end of each experiment. This amount is reduced to gram mol. and used for examining the nature of absorption of ions.

Absorption of component ions of individual salts

Calcium nitrate: In the first instance the absorption of component ions of each salt during the period of experimentation is studied with respect to all the three crops. The data for the absorption of calcium nitrate (Table I) would clearly show that the component ions of calcium nitrate are absorbed in varying proportions bearing no definite ratio. The nitrate ion in all the three crops is absorbed in greater quantity than the calcium ion and the difference becomes more marked with advance in age.

TABLE I

Absorption of calcium and nitrate ions in gram mol. by the roots of linseed, wheat and paddy (100 plants) at successive stages during the life-cycle.

Age in weeks	Linseed		Paddy		Wheat	
	Ca	NO_3	Ca	NO_3	Ca	NO_3
I.	...	...	...	...	0.00027	0.0030
II.	0.1371	...	0.000124	0.00059	0.00045	0.0063
III.	...	...	0.000410	0.00785	0.00036	0.0140
IV.	0.0670	...	0.000886	0.00172	0.00049	0.0030
V.	0.0233	0.0284	0.001900	0.00270	0.00022	0.0070
VI.	0.0137	0.0373	0.005180	0.00943	...	...
VII.	0.0074	0.1222	0.007550	0.01800	...	...
VIII.	...	...	0.010100	0.03240	...	...

The differential intake of ions of a single salt contained in a triple medium is thus made evident not for a period of few hours only but for a greater portion of the life-cycle of the plants experimented upon.

Magnesium sulphate: Similar unequal absorption of ions is found to occur in the case of magnesium sulphate (Table II).

TABLE II

Absorption of magnesium sulphate ions in gram mol. by the roots of linseed, wheat and paddy (100 plants) at successive stages during the life-cycle.

Age in weeks	Linseed		Paddy		Wheat	
	Mg	SO_4	Mg	SO_4	Mg	SO_4
I.	...	...	...	...	0.000315	0.000181
II.	0.17880	0.04384	0.00046	0.00100	0.000324	0.000275
III.	...	...	0.00082	0.00128	0.000350	0.000590
IV.	0.08103	0.05949	0.00088	0.00177	0.003650	0.000184
V.	0.01072	0.01824	0.00094	0.00221	0.000322	0.004000
VI.	0.01072	0.01848	0.00082	0.00665	...	...
VII.	0.07929	0.00838	0.00097	0.00860	...	...
VIII.	...	...	0.00145	0.00959	...	...
IX.	...	...	0.00165	0.01110	...	...

At all stages of the life-cycle as in calcium nitrate, in none of the crop plants experimented upon does magnesium absorption equal that of sulphate. In paddy, the acidic ion is absorbed in greater proportion in comparison to the basic one and the difference becomes pronounced as the age advances. In linseed however, during the first two periods, cations are absorbed in excess of the anions. The order is subsequently reversed and the latter gains over the former for two successive periods after which the first order is found to repeat again, the anions showing distinctly less absorption than the cation. In wheat also cations are absorbed in excess of anions during the first, second and fourth periods of observation, while in the third and the fifth reverse is the case.

Potassium bi-phosphate: The inference regarding the differential absorption of ions drawn in the previous cases finds further support from the data obtained for potassium bi-phosphate (Table III).

TABLE III

Absorption of potassium and phosphate ions in gram mol. by the roots of linseed, wheat and paddy (100 plants) at successive stages during the life-cycle.

Age in weeks	Linseed		Paddy		Wheat	
	K	PO_4	K	PO_4	K	PO_4
I	...	...	...	...	0.00292	0.00260
II.	0.05312	-0.01840	0.0024	0.00036	0.00380	0.000240
III.	...	...	0.0050	0.00098	0.00400	0.000200
IV.	0.04239	0.00028	0.0112	0.00125	0.00430	0.000197
V.	0.05168	0.01936	0.0124	0.00129	0.00450	0.000170
VI.	0.03084	0.01352	0.0280	0.00176	...	...
VII.	0.07744	0.01504	0.0320	0.00315	...	...
VIII.	...	...	0.0480	0.00930	...	...
IX.	...	...	0.0300	0.00670	...	...

Unlike the previous two cases the relative absorption of the two ions of this salt differs in certain respects. In paddy the cations are absorbed in greater proportion than the anions with the only exception in the second week. The differential absorption in this case also becomes pronounced as age advances. In case of linseed, potassium ions are found to be absorbed in greater quantity than the phosphate ions at successive stages of observation. The absorption of phosphate ions in contrast to those of potassium is not at all marked during the early stages and it is noteworthy that when the plants are a week old, a definite excretion of phosphate ions is noted. Wheat too indicates a greater absorption of potassium over that of phosphate thereby indicating a similarity in the nature of unequal absorption of potassium bi-phosphate by as many as three crop plants experimented upon.

As a natural outcome of experimentation, therefore, it becomes obvious that unequal absorption of the component ions of individual salts appears to be as characteristic a feature of complete nutrient solution as that of single salt media (Meurer 1909, Pantanelli 1915, Redfern 1922, Stiles 1924). The occurrence of the phenomenon in all the three crops clearly indicates that unequal absorption is of general occurrence in plants of different biochemic constitution. Thus unequal absorption is not restricted to single salt solutions in experiments ranging over short durations alone but is true of balanced multi-salt solutions and long range experiments as well, irrespective of the end products of metabolism in different plants.

Induced reaction in the culture solution due to ionic absorption

In Table IV are portrayed the values of total absorption of anions and cations in succession against the age of plants. On the basis of the final strength of cations and anions the expected acidity or alkalinity is expressed for each experiment.

TABLE IV

Absorption of total anions and cations in gram mol. per 100 plants and the observed and calculated acidity or alkalinity of the solution as compared to original H-ion concentration.

Age in weeks	Cations	Anions	Calculated acidity or alkalinity	Observed acidity or alkalinity
		LINSEED.		
V.	0.08576	0.06600	Acidic	Acidic
VI.	0.05528	0.06936	Alkaline	Alkaline
VII.	0.16418	0.14562	Acidic	Acidic
		PADDY.		
II.	0.002985	0.005200	Acidic	Acidic
III.	0.006429	0.003049	Alkaline	Alkaline
IV.	0.012998	0.004740	”	”
V.	0.015370	0.006200	”	”
VI.	0.033994	0.017840	”	”
VII.	0.040520	0.029730	”	”
VIII.	0.059580	0.049360	”	”
IX.	0.039500	0.060830	Acidic	”

It would appear from the values (Table IV) that the total anions and cations are absorbed in varying proportions. This does not hold true only for a limited period of observation but is equally characteristic of experiments conducted over long range extending throughout the life-cycle of plants. In all the three crops experimented upon, the same phenomenon is observed emphasising thereby the possibility of its being identified as a characteristic feature of absorption in plants as a whole.

The expected acidity and alkalinity of the solution consequential to such an absorption is further compared with the observed pH value of the solution at different stages of plant growth. The expected acidity calculated from the absorption of cations and anions portrayed in table IV when brought together and compared with the observed pH values (Fig. I) period for period, shows a striking similarity in each experiment, the only exception being found towards the last period of observation in paddy.

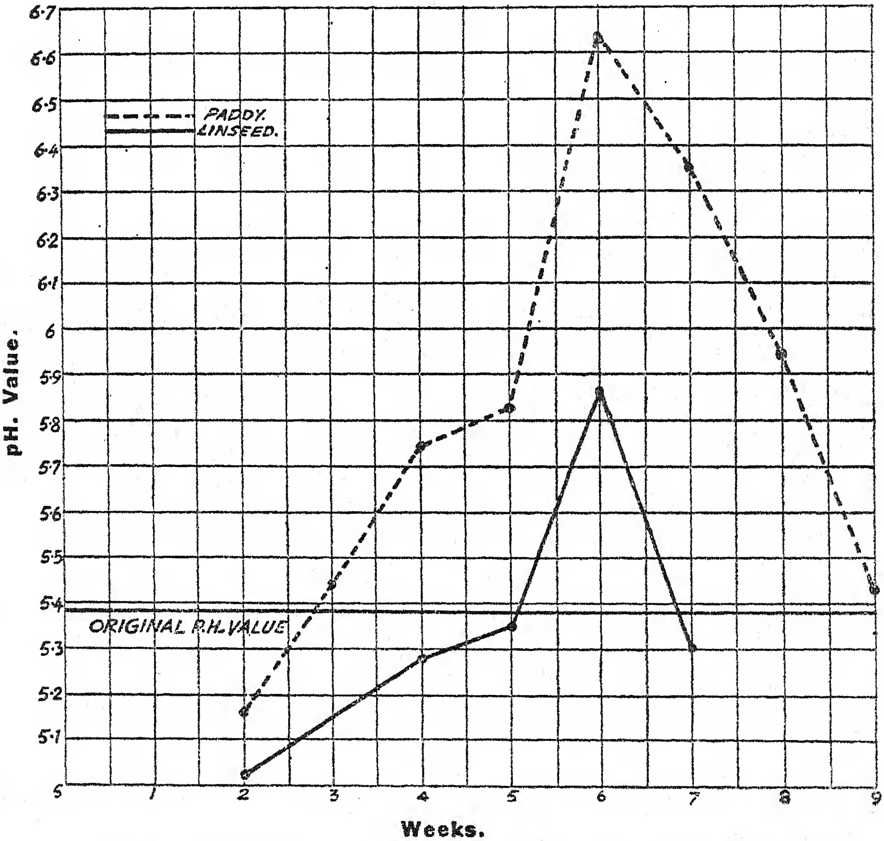


Fig. 1. pH values of the nutrient solution at successive stages of the life-cycle.

The order of entry of ions

Although the present study as to the order and rate of entry of ions has not been directed to claim an independent investigation along the lines of Stiles and Kidd (1919) and other workers in the field, we thought we might usefully analyse our data in the above light. This has been done to elucidate in the first place whether the order observed for single salt solutions equally holds good for multi-salt media; and secondly, instead of keeping the cations and anions fixed as in previous investigations variations in the quantity of these ions of different charge have been secured by providing a three salt media in order to study their subsequent influence on the order of entry of ions.

The order of entry from a complete nutrient medium into plants growing for a long time need not necessarily be the same as observed by these authors from single salt solutions during short intervals. This may be so, since plant tissues may or may not actually need these ions for purposes of metabolism. Moreover, the rate of entry from single salt solution may not ordinarily give a true picture of the order. In the experiments above referred to, however, the absorption is dependent not only upon the position of equilibrium and the antagonism of salts but upon other internal and external factors as well.

Table V indicates that in paddy plants the order in the first two weeks as regards the absorption of cations is K-Mg-Ca, but it changes to K-Ca-Mg, in the next five weeks and again reverses in the last week to K-Mg-Ca. The order of the intake of anions in the first three weeks is S-N-P, S-P-N, and S-N-P, respectively and in the remaining it is N-S-P.

In linseed for cations the order Mg-Ca-K is kept up for a period of first four weeks after which it changes to K-Ca-Mg. This order continues for the next two weeks following which the series Mg-K-Ca is obtained. Of the anions N seems to occupy the first place at least in those experiments, the values for it are available.

As to the position of S and P there is always an interchange.

TABLE V

Order of entry of ions at successive stages of growth of wheat, linseed and paddy.

	Paddy		Linseed		Wheat	
Age in Weeks	Kations	Anions	Kations	Anions	Kations	Anions.
I.	K Mg Ca	S N P	..	..	K Ca Mg	N S P
II.	K Mg Ca	S P N	Mg Ca K	S P	K Ca Mg	N S P
III.	K Ca Mg	S N P	..	..	K Mg Ca	N P S
IV.	K Ca Mg	N S P	Mg Ca K	S P	K Mg Ca	N S P
V.	K Ca Mg	N S P	K Ca Mg	N P S	K Mg Ca	N P S
VI.	K Ca Mg	N S P	K Ca Mg	N P S	......	......
VII.	K Ca Mg	N S P	Mg K Ca	N P S	......	......
VIII	K Mg Ca	N S P	..	..	......	......

In wheat plants, the order K-Mg-Ca is kept up on the first, fourth, and fifth periods of observation, the order in the intervening periods being K-Ca-Mg. Of the anions like the previous case, N occupies the first place and the rest two interchange their position.

A comparative study of the data available for all the three crops clearly points out that in fifteen cases out of eighteen K occupies the first position, all the exceptions occurring in linseed which is fundamentally different in its constitution from the other two. Of anions N is found to occupy the first place in thirteen out of sixteen cases and the deviations occur only during the first three periods of the life-cycle of paddy. It is interesting to note that the order of cation as determined by Stiles and Kidd (1919) begins with K at its head. In case of anions N comes first at a later stage. The results obtained by Fitting (1915), Trondle (1918), Kahho (1921) are in accordance with the present one. These authors have shown that K and N maintain the first position from the very beginning. It would thus appear that the rate of entry of K and N is the same in both single and three salt solutions. Excepting K and N the rest of the ions do not seem to have any definite regularity as to their order. The order of their entrance appears to be a function of the age and developmental stage of the plants and their physiological requirement at different periods of the life-cycle.

Rate of entry of ions

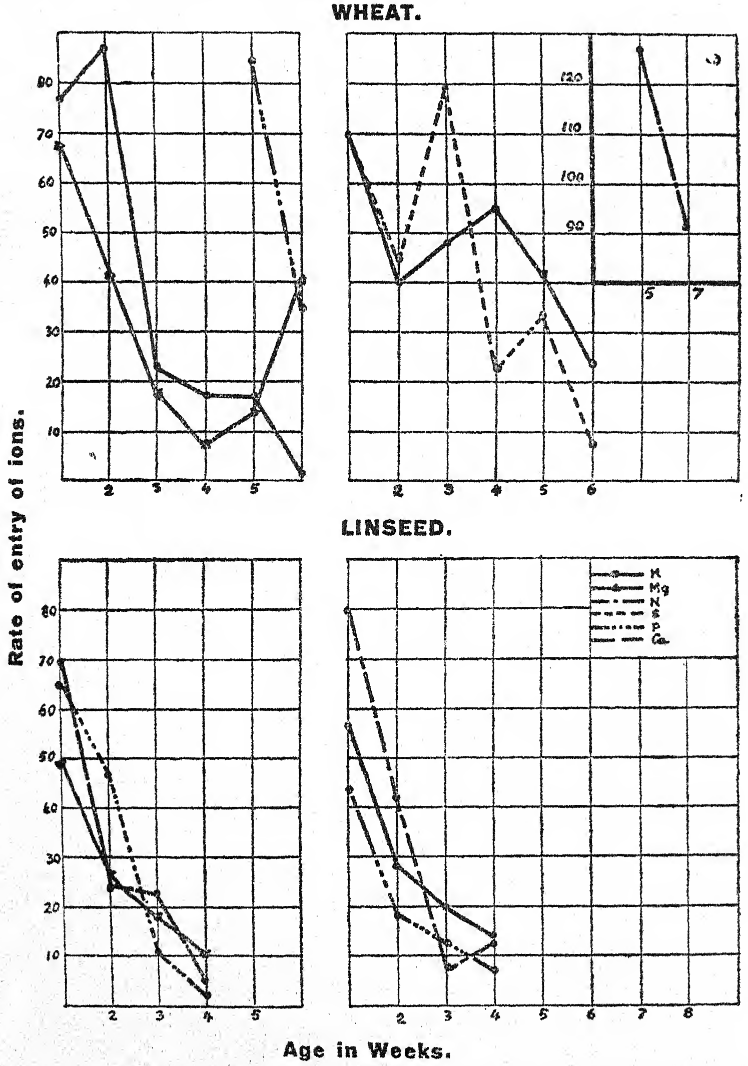
The rate of entry of ions has been calculated as percentage weekly absorption on the basis of the formula $R/100 = \text{Log}\hat{e}\ W_2 - \text{Log}\hat{e}\ W_1$, where W_2 indicates the quantity of ions at the end of the week and W_1 that contained in the beginning per plant.

An examination of Figs. II—IV will reveal that for linseed the rate of entry of K ion to start with is high and shows a general fall with the exception of a rise in the second and third weeks. It would thus appear that during the early stages the rate of absorption is highest and with the advance in age it falls down. The rate of calcium absorption on the other hand increases during the first week after which the curves take a down-hill course. Towards the later periods of observation however, the rate of entry becomes inappreciable as in the case of potassium.

The rate of magnesium absorption is high in the beginning, shows a precipitous fall till the fifth week and subsequently a gradual rise. The rise in the sixth and seventh weeks at a time when the rate of entry of K and Ca shows a characteristic fall is indeed significant.

On examining the relative absorption values of anions we notice the same general fall as was observed with respect to kations. Thus for instance, the absorption rate curves for sulphate ion after describing two maxima in the fourth and sixth weeks in general, shows a decline with advance in age. The values obtained for nitrate and phosphate though few in number support the above observation.

In wheat also the rate of absorption of all the ions (the only exception is nitrogen in the fourth week) shows a regular decline throughout the vegetative period and resembles linseed in this respect. It may thus be inferred that with advance in age of the plants up to the end of the vegetative life-cycle the rate of absorption of both anions and kations shows a decided fall.



Figs. 2 and 3.—Rate of intake of different ions by the roots of wheat and linseed.

Unlike the previous cases the data obtained for rice range over both the vegetative and reproductive cycles. These two periods in the life-cycle are distinct as regards the rate of ionic absorption. The vegetative cycle ending in the fourth week is characterised by a general fall in the rate of absorption. With the onset of the reproductive phase, however, the rate shows an increase in all cases which after reaching a certain maximum is followed by a gradual fall as in the case of N, Ca, K and S. In the case of Mg and P the rate, however, increases up to the end of the life-cycle. Continuous rise in the intake of Mg and P up to the end of the life-cycle when the grain formation is taking place in contrast to the fall in the rate of intake of other ions stresses the greater need of Mg and P towards the seeding stage.

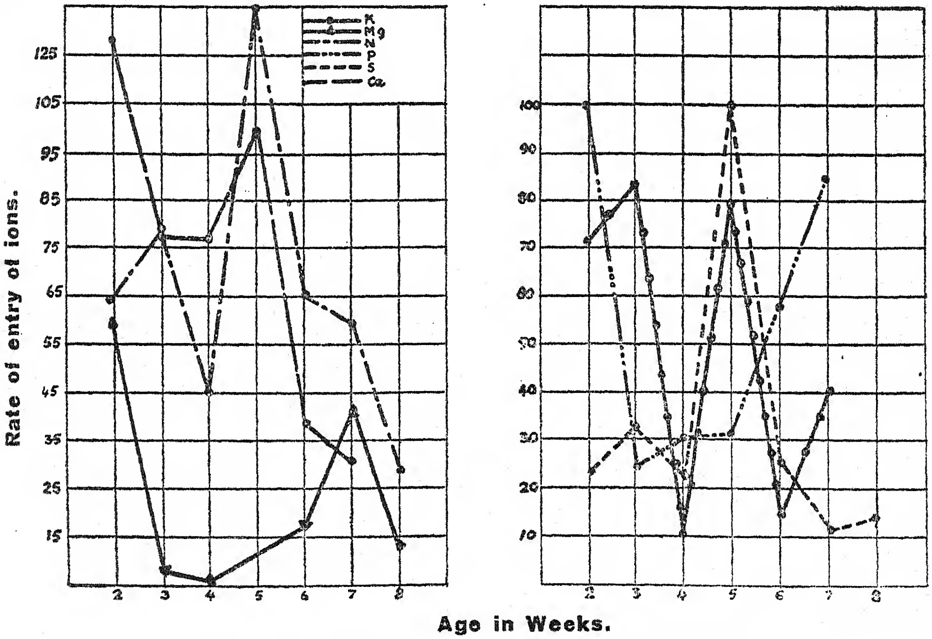


Fig. 4.—Rate of intake of different ions by roots of Paddy.

Summary and Conclusions

In the present communication, crop plants of different biochemic constitution like wheat, paddy and linseed are raised in Shive's 3-salt culture solution. The absorption of component ions of the different salts constituting the medium is systematically studied at successive stages of growth of these plants. The data so obtained are examined from the point of view of the relative amount of absorption taking place from the solution, the order and rate of entry of ions, and the changes in the reaction of the culture medium consequential to such an absorption. The studies have been extended to long range of experimentation in case of plants of varying biochemic groups in order to throw light on the process of absorption as it takes place in crop plants in general during their entire life-cycle.

The verdict of the experimental enquiry leads to the following conclusions :—

The phenomenon of unequal absorption is not restricted to single salt solutions and to shorter durations alone but is true of balanced solution as well for the entire or a part of the life-cycle of plants of different biochemic constitution.

The experimental results seems to indicate that in case of plants growing during long range experimentation, the hydrogen and hydroxyl ions are mainly responsible for unequal absorption.

As to the order of entry, K and N are found to be absorbed in greater proportion in majority of cases indicating thereby that the mobility of these ions follows more or less the same order in both single and multi-salt solutions. The rest of the ions do not show any regularity as to their order and the absorption seems to be determined by the specific requirement of plants at successive stages of growth.

The rate of the entry of ions declines with the age of the plant during the vegetative period. With the onset of the reproductive phase the rate, however, increases to fall again towards the close of the life-cycle.

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A NOTE ON THE DEVELOPMENT OF THE EMBRYO-SAC IN *PHRYNIUM CAPITATUM* W.

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The family Marantaceae according to Bentham and Hooker(1) has 10 genera and 36 species in India. The plants are mostly herbs and some of them are of economic importance.

The literature on the embryology of plants belonging to this family appears to be meagre. There are brief accounts of the different embryological stages of *Phrynium*, *Calathea*, *Maranta* and *Thalia*. Humphrey(2) (1896) and Schachner(3) (1924) worked on the embryology of *Thalia* species. Humphrey studied the development of the seed from the ovule in the genera *Maranta*, *Calathea*, *Myrosma* and *Thalia* and also recorded, from a section of an ovule of *Thalia dealbata*, the normal arrangement of the eight nuclei in the gametophyte. His investigations revealed the presence of 'perisperm canal' — the characteristic feature in the family Marantaceae. Schachner(3) found an eight nucleate embryo-sac in *Thalia* species and suggested that the antipodals are probably ephemeral.*

Material and Methods

The material for the present study was collected from the Royal Botanical Gardens, Calcutta, and identified from the Herbarium of the same place. The inferior ovary was dissected out separately and fixed in different fixatives. Nawaschin's fluid gave best results and was later used exclusively. The material was dehydrated and cleared in the usual way, embedded in paraffin and sections were cut 8-14μ thick. Heidenhain's iron alum haematoxylin was used for staining.

Development of the ovules and the integuments

Phrynium belongs to the tribe Phrynieae which is distinguished from the only other tribe Marantaeae of the family Marantaceae in that the ovary is trilocular and each loculus contains one fertile ovule.

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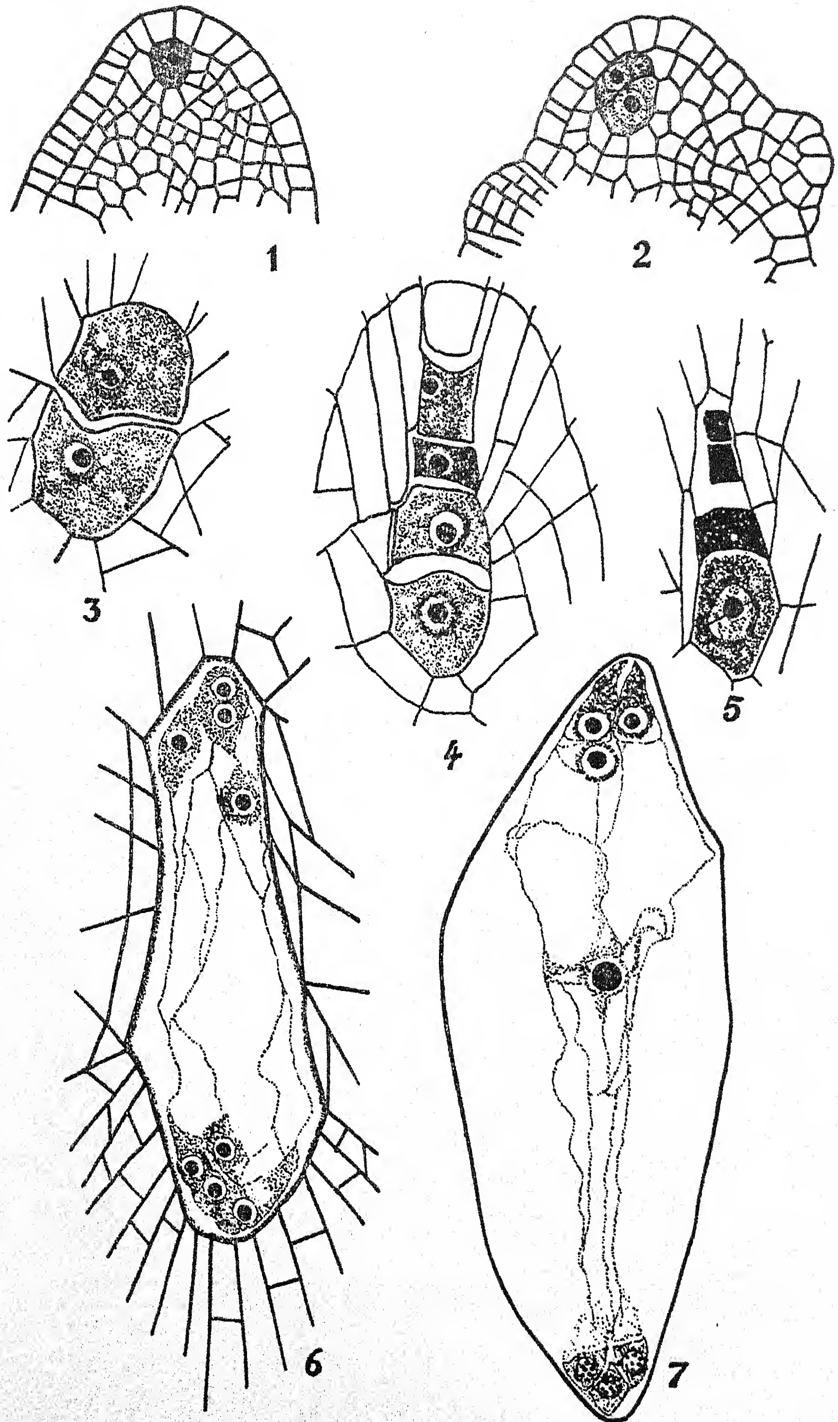
* A comparative account of the embryology of Scitamineæ has been recently published by Mauritzon since the paper was sent to press.

J. Mauritzon - Lunds Universitets Arsskrift N.F. Ard 2. Bd 31. Nr. 9.



Figs. 1—7. *Phrynium capitatum* W. Fig. 1. Differentiation of single hypodermal archesporial cell; Fig. 2. Division of the archesporial cell into cover cell and the megaspore mother cell; Fig. 3. Dyad; Fig. 4. Normal linear tetrad; Fig. 5. Degeneration of the upper three megaspores. Fig 6. 4-nucleate embryo-sac; Fig. 7. Mature embryo-sac before fertilisation.

Due to the increased growth at an early stage, the tip of the nucellus and also the corresponding parts of the integuments, bend considerably against the funiculus and ultimately the ovule assumes a campylotropous form. The attachment of the ovule is by a funiculus which is short and fleshy and into which the vascular bundle passes from below.

The primordia of the integuments are first noted after the differentiation of the archesporial cell. They first appear as annular outgrowths from the base of the nucellus. The inner integument is only two cells thick; the outer integument is more massive and is more than four cells in thickness. It subsequently encloses the inner integument and these two together form the micropyle.

The development of the embryo-sac

A single archesporial cell differentiates in the hypodermis. It is comparatively bigger than the surrounding cells and contains a conspicuous nucleus and dense cytoplasm (Fig. 1). The presence of more than one archesporial cells has not been noted. The archesporial cell cuts off a wall-cell and then functions as the megaspore-mother-cell (Fig. 2). The megaspore-mother-cell increases in size and its nucleus divides into two, cell wall being formed between the daughter nuclei after the completion of the reduction division, giving rise to a dyad (Fig. 3). As a result of the homotypic division a normal linear tetrad of four megaspores is produced, each being delimited from the other by distinct walls (Fig. 4). The chalazal megaspore soon begins to enlarge and forms the uninucleate embryo-sac. The cytoplasm becomes markedly vacuolated during this stage. Almost simultaneously the degeneration of the upper three megaspores is noted (Fig. 5). The nucleus soon divides and forms the binucleate embryo-sac. The embryo-sac cavity further increases in size and a big central vacuole is formed. The two nuclei pass on to the two ends of the embryo-sac and there divide twice in succession and give rise to the eight nucleate embryo-sac (Fig. 6). In this stage it is possible to make out the polar nuclei on account of their position. The two nuclei close to the micropylar end form the synergids and the one next to them differentiates as the egg. The synergids are pear-shaped cells and have prominent vacuoles at their lower ends. No filiform apparatus has been noted. At the eight-nucleate stage, the four chalazal nuclei lie in the chalazal end of the embryo-sac. The polar nucleus moves up from the chalazal end of the embryo-sac and fuses with the upper polar nucleus near the centre of the sac and gives rise to the 'fusion nucleus'. The antipodals which are three in number and triangular in shape remain in the chalazal end of the embryo-sac and do not show any sign of degeneration till the time of fertilization (Fig. 7).

Summary

The mature ovule is campylotropous; a single archesporial cell develops in the hypodermal layer of the nucellus and cuts off a parietal cell and then functions as the megaspore-mother-cell. The megaspore-mother-cell gives rise to a normal linear tetrad of which the chalazal megaspore develops and forms an eight nucleate embryo-sac. The polar nuclei fuse and the antipodals persist up to the time of fertilization.

My thanks are due to Mr. I. Banerji who initiated me in this line of work and helped me with his advice throughout the course of the investigation.

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DEVELOPMENT OF EMBRYO-SAC AND ENDOSPERM-HAUSTORIA IN SOME MEMBERS OF THE SCROPHULARINEAE

Part I

An account of *Sopubia delphinifolia* G. Don. and *Alonsoa* sp.

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Introduction

The two members *Ilysanthes* sp. and *Bonnaya* sp. have already been studied and the observations have been read during the Indian Science Congress sessions of the years 1929 and 1931. A paper dealing with the two genera is ready for publication. The single massive integument, a well-developed tapetal layer from the integument, the reduced nucellus and the development of linear tetrad of megaspores directly from the hypodermal initial cell and lastly the development of the embryo-sac from the innermost magaspore have formed almost the characteristic and constant feature of many families of sympetalae in general and Scrophularineae in particular. The different degrees of tapetal formation, their origin and cell contents and their relationship to the parasitic or nonparasitic nature of a member have been dealt with at elaborate length by Balicka (1889) and Miss Mitchell (1915). Even in these two genera already studied, the tapetum surrounds the tapering part of the embryo-sac, accumulates nutritive material and, by the division and enlargement of its cells, keeps pace with the enlarging embryo-sac after fertilization. The reduced antipodals have also been observed as in other members of the family and their reduced size has been ascribed to the want of space in the chalazal end of the embryo-sac for their full development. Although the antipodals are persistent in some of the genera, it is still found that the same in *Ilysanthes* and *Bonnaya* disorganise immediately after fertilization.

The formation of the secondary nucleus from the two polar nuclei has been observed in the two genera studied, while in members like *Veronica* and *Melampyrum* no fusion has been observed. The genera *Pedicularis* and *Tozzia* show fusion as well as nonfusion prior to fertilization. Fertilization has been studied in *Linaria vulgaris*, *Digitalis purpurea*, *Pedicularis foliosa*, *Melampyrum sylvaticum* and others.

The endosperm formation has always been an interesting feature of Scrophularineae. In a few members free nuclear division of the primary endosperm nucleus has been reported and these free nuclei have been observed to get into the vermiform haustoria developing from the micropylar and chalazal ends of the embryo-sac. This kind of coenocytic haustorium is a common occurrence in the families Campanulaceae, Lobeliaceae and Stylidiaceae. But in most of the members observed so far, cell-wall formation from the first division of the primary endosperm nucleus is the usual procedure, and subsequent divisions of this followed by wall-formation result in regularly arranged tiers of cells filling the embryo-sac. Of these only the middle ones develop into the endosperm, while towards the two ends the tiers devlop into the haustoria. In members like *Linaria* and *Antirrhinum* division of the primary endosperm nucleus initiates the separation of the micropylar half from the chalazal half, the former developing into the endosperm, while the latter forms the chalazal haustorium.

While haustoria of diverse morphological origin have characterised many members of other families, it has been observed that so far the endosperm haustoria form the constant feature of many members of Scrophularineae. Careful study of many of the genera of this family has shown that the greatest variation is among the members with cell formation instead of free nuclear division. The chalazal and micropylar haustoria present in many of the members are of different shapes and varying sizes. At times only one kind is present while at other times both kinds develop. If both kinds are present, one kind develops at the cost of the other, and there is periodicity also exhibited by these haustoria. The kind of haustorium present, its shape, size and structure, and the duration of its activity depend upon the degree of demands made by the developing embryo and endosperm on the stored-up food material, their period of dependence and the available nutrition in the neighbouroood and the quality of the nutrition. There are aggressive as well as nonagressive haustoria. The two kinds may be present in the same form as in *Ilysanthes* or in different genera altogether.

Later stages of haustoria often reveal hypertrophied nuclei in all stages of disintegration presenting a coenocytic appearance. Dense cell-contents taking a dark stain have always characterised older haustoria. Even cellulose or lignin deposition on the walls of haustoria has been observed in many members, while, in a few, cellulose threads have been found to traverse the older haustoria. Notwithstanding the common occurrence of this deposition, the exact significance has yet to be definitely understood.

Since the nuclei of the two members studied were very small, the cytological study and the determination of the chromosome number had to be given up. Notwithstanding this handicap in almost all the members of the family, an effort has been made to study this aspect also, especially in *Sopubia* sp., an account of which is given below. As this is a root parasite also, it may throw fresh light on the problem of relationship between the parasitic nature of an individual and the endosperm haustorial formation. The other member selected for the study is *Alonsoa* sp. a foreign plant introduced into the gardens of Ootacamund, Nilgiris, on account of its attractive flowers. Observations on these two members have already been communicated and read during the Indian Science Congress Sessions of the years 1933 and 1934. A full account of the same is given below.

Sopubia delphinifolia G. Don.

The material for investigation was collected on warm days between 12 noon and 3 p.m. and fixed in weak chrome acetic acid solution with osmic acid. The sections were cut 7 microns thick for the study of pollen and embryo-sac development, while, for the observation of the embryo and haustorial development the sections were cut 10 microns thick. Considerable difficulty was experienced during section cutting on account of high lignification of the older ovary wall the removal of which resulted in the detachment of young seeds from the placenta because of the delicate nature of the funicle. All the sections were stained in Heidenhain's iron alum haematoxylin.

Development of Embryo-Sac:—All the anatropous ovules are placed on the massive placenta the cells of which are filled with starch grains. A few of the cells showed many oil globules also. The nucellar tissue is very much reduced and there is a thick integument from which the tapetum develops at a later date. During the pollen tetrad stage the nucellus is well defined and the hypodermal archesporial cell is differentiated from the other neighbouring cells of the tissue by its larger size, larger nucleus and the rich cell contents. Notwithstanding the small size of the nucleus and the chromosomes, the stages in the nuclear division in the archesporial cell have been studied and the number of bivalents has been found to be 18 as shown in fig. 2. After the first and second divisions of the nucleus followed by wall formation, a linear tetrad develops as in fig. 3. As in the other members already studied, the innermost of the tetrad of megaspores develops into the embryo-sac with the enlarged micropylar and the tapering chalazal ends, the typical egg apparatus, polar nuclei and the reduced antipodals. The protoplasm is vacuolated and is dense in the neighbourhood of the egg apparatus and the olpar nuclei. Just before fertilization instead of the two polar nuclei there is a single nucleus although the various stages in the nuclear fusion have not been studied. The jacket layer or tapetum keeps pace with the elongating embryo-sac and surrounds the entire sac up to a certain stage after which it is observed that only the tapering narrow end of the embryo-sac has the sheathing tapetum while the dilated end is devoid of this jacket layer as seen in figs. 4 and 5.

Fertilization:—Although the stages of fertilization have not yet been studied, mention may still be made about the destruction of one of the synergids during fertilization and about the degeneration and disappearance of the synergids and antipodals soon after fertilization.

Embryo and Endosperm formation:—A careful study of the development of the embryo shows that the stages are similar to those of a typical dicot embryo; and it is superfluous to describe these stages elaborately. But the development of the endosperm is very interesting. The primary endosperm nucleus divides and the first division is followed by transverse wall-formation. A second division takes place in the cell towards the micropyle thereby resulting in a row of three cells, the chalazal cell, the middle cell and the microphylar cell. The middle cell by a series of divisions later on gives rise to the endosperm tissue. Towards the two ends of the embryo-sac the endosperm cells are smaller than the other cells and show dense cell contents and in all probability do the food conducting work instead of storage. The other two cells enlarge and by further development give rise to the two kinds of haustoria. The starch grains are deposited in the endosperm tissue and some of the cells at times even show a binuclear stage.

Chalazal and Micropylar Haustoria:—The first formed chalazal cell enlarges and later on divides resulting in two large uninucleate cells. These develop enormously into long tube-like haustoria with dense contents eating their way into the chalazal tissue and establishing direct contact with the vascular elements in the hilum. These begin their activity at a later stage and supply the developing endosperm with the nutritive material absorbed from the integument. The dense cell contents of the chalazal tissue bear testimony to this fact. Later on the haustoria show a tendency towards fusion by the dissolution of the separating wall as shown in figs. 12 and 13, resulting in a binucleate body. Older stages of the haustoria show the hypertropied and disintegrating nuclei and the thick deposition of cellulose on the wall of the haustorium and embryo-sac as in figs. 11, 12 and 13.

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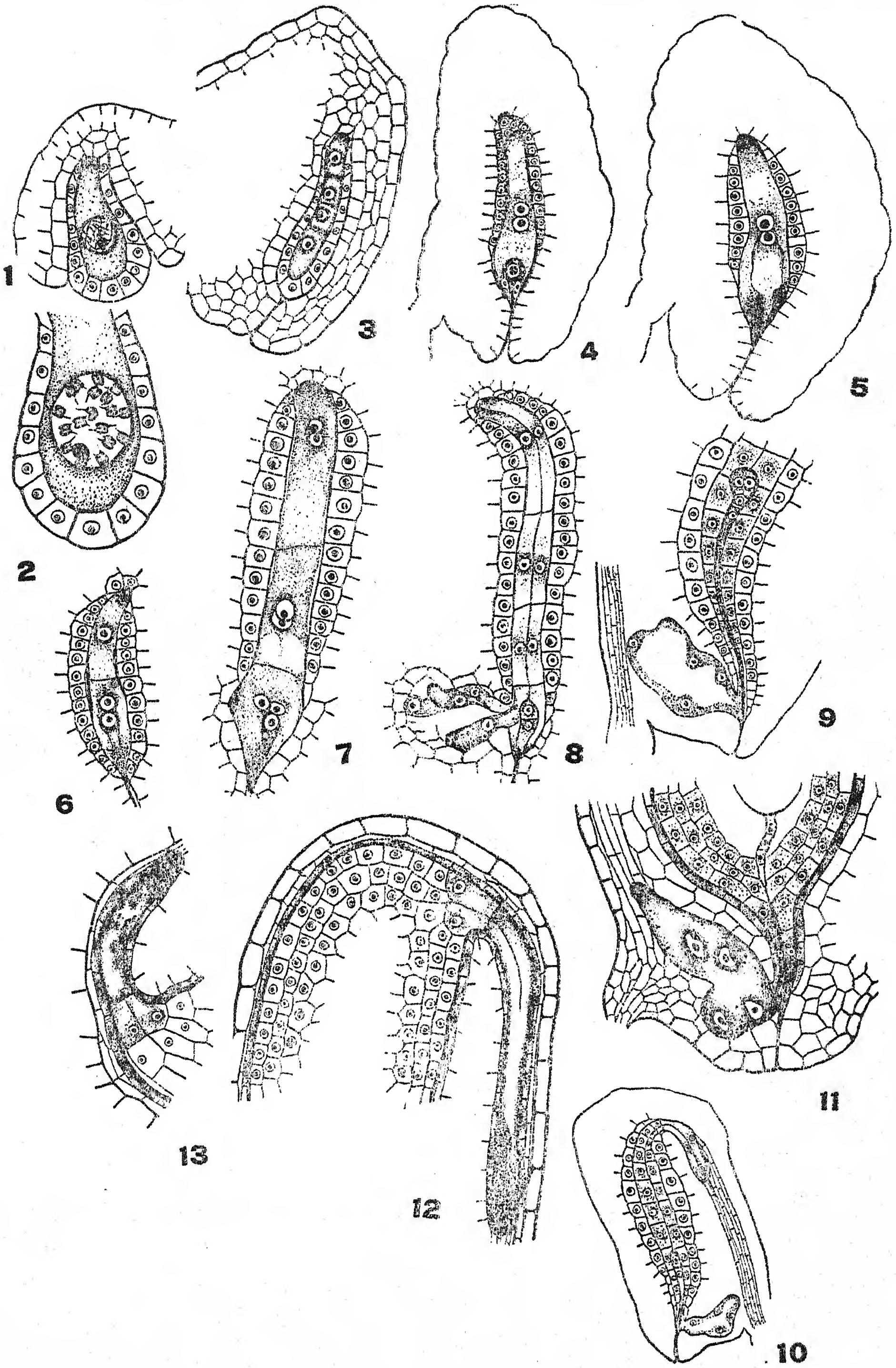
first division of the primary endosperm nucleus cutting off the micropylar half from the chalazal half of the embryo-sac. × 400. Fig. 7. The formation of a middle cell, and early stage in the formation of micropylar and chalazal haustoria. × 200. Fig. 8. Formation of the embryo and the two kinds of haustoria. × 200. Fig. 9. A coenocytic micropylar haustorium, and the development of the embryo. × 120. Fig. 10. Development of the two kinds of haustoria. × 40. Fig. 11. Amoeboid hypertropied nuclei of old micropylar haustorium, and thickening of the inner wall of tapetum. × 200. Fig. 12. Old chalazal haustorium binucleate owing to the dissolution of the partition, and the hypertropied nuclei. × 200. Fig. 13. Disintegration of the nuclei in the old chalazal haustorium. × 200.



Figs. 1—13. *Sopubia delphinifolia* G. Don. Fig. 1. Development of the nucellus. × 400. Fig. 2. Diakinesis in the magaspore mother cell. × 1000. Fig. 3. Formation of the linear tetrad of megaspores. × 400. Fig. 4. Embryo-sac with the tapetum. × 200. Fig. 5. Synergids and antipodals degenerating after fertilization. × 200. Fig. 6. The

The cell towards the micropyle divides twice longitudinally and gives rise to four uninucleate micropylar haustoria. These are simple unbranched and vermiform and aggressively act on the integument. All these drill a hole towards the hilum as in figs. 9 and 11. most aggressively eating their way deeper into the tissue of the integument till they almost reach the vascular traces. At this stage all the haustoria fuse and enlarge resulting in a coenocytic haustorium with four nuclei and with several lobes some of which almost reach the outermost layer of the integument as in fig. 11. During the older stages the micropylar haustorium shows dense cell contents and the thick deposition of cellulose on its wall. The nuclei are hypertrophied and are amoeboid in shape.

Since the haustoria absorb nutrition from the integument and send it on to the developing endosperm inside, the modification of some of the terminal endosperm cells into the conducting elements has been a constant feature in many members.

Alonsoa Sp.

The time of fixation and the reagents used for fixing and staining the material were the same as before. The sections for the study of the embryo-sac were cut 8 microns thick, and for the development of the embryo and endosperm 12 microns thick. On account of the handicap of the small nucleus in this form also the cytological aspect was not taken up.

Embryo-Sac:—Since the stages in the formation of the embryo-sac were the same as in *Sopubia*, an elaborate account of the nucellus and the linear tetrad development was found superfluous. The fully developed embryo-sac with all its details has been shown in fig. 14. The small synergids and antipodals and the two polar nuclei forming the secondary nucleus have already been shown. The massive integument and the slightly reduced tapetum are seen in this form. In the embryo-sac as well as in the cells of the integument plenty of starch grains are seen. The abundant supply of nutrition to the embryo-sac just before fertilization is rather an interesting aspect. Especially in the embryo-sac they are concentrated in the neighbourhood of the egg and the secondary nucleus.

Fertilization:—Several stages in the fertilization have been observed and the same have been shown in the figures. One of the synergids is destroyed during fertilization; and as regards the antipodals it may be mentioned that they persist during the early stages of endosperm formation. The sperm nuclei have been observed associated with the egg cell and the secondary nucleus.

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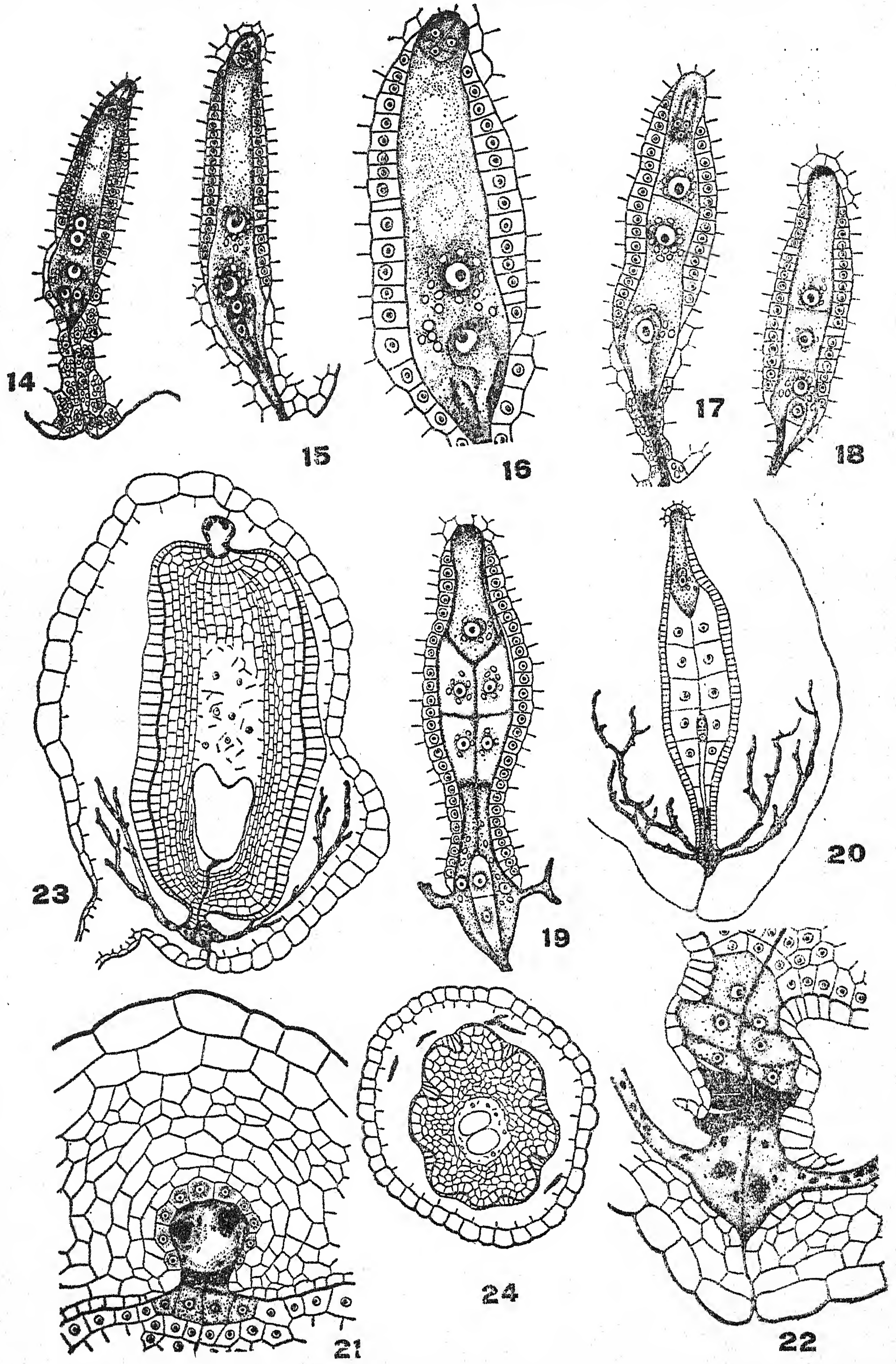
chalazal haustorial cell and the persistentantipodals. × 200. Fig. 18. Initiation of the formation of micropylar haustorium. × 200. Fig. 19. Development of the uninucleate micropylar and chalazal haustoria. × 200. Fig. 20. Advanced stage of the above. × 100. Fig. 21. Older micropylar haustoria with the hypertrophied nucleus about to disintegrate. × 200. Fig. 22. Older chalazal haustorium binucleate and with the hypertrophied nuclei. × 200. Fig. 23. Section showing the position of the haustoria and embryo. × 120. Fig. 24. Transverse section of a young seed with the various structures. × 40.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Figs. 14—24. *Alonsoa* sp. Fig. 14. Embryo-sac with the tapetum, × 200. Figs. 15 & 16. Stages in fertilization. × 200 & × 450 respectively. Fig. 17. Separation of the

Embryo and Endosperm:—Some of the stages in the development of the embryo have been observed and these are of the *Capsella* type. It is interesting to note that the development of the embryo is rather slow, and during the early stages of the endosperm the activity of embryo formation is not appreciable. Accumulation of starch grains in the embryo-sac before and after fertilization and the poor size of the tapetum with reduced cell contents characterise this member.

As regards endosperm formation there is a similarity to *Sopubia* during the earlier stages. Just as in the previous form the first division of the primary endosperm nucleus results in the wall formation cutting off the chalazal half from the micropylar half of the embryo-sac; division of the micropylar cell thus formed will result in a row of three cells in the embryo-sac. The middle cell by a series of longitudinal and transverse divisions gives rise to the endosperm arranged in tiers as in figs. 19 and 20 while the other two cells by further divisions develop into the haustoria. Starch grains are abundantly found in all the endosperm cells, and at times in haustoria also. The transverse section of the seed shows the lobed nature of the endosperm tissue which has developed and encroached upon the integument and the tapetum as in fig. 24. During this stage thickening of the inner wall of the tapetum has been observed which in all probability serves a mechanical function.

Endosperm Haustoria:—The cell towards the micropyle divides twice longitudinally giving rise to four uninucleate haustoria. These are tubelike outgrowths to begin with, but, later on each of these develops into a highly branched vermiform haustorium traversing the intercellular spaces in the neighbourhood and at times even destroying the inner cells of the integument and reaching its outermost layer. The rich cell contents and the countless number of starch grains characterise these bodies. Later stages show the amoeboid nuclei just prior to disintegration.

The chalazal haustoria are two in number and develop from the chalazal cell by a longitudinal division. These are short club-shaped cells with their dilated ends towards the endosperm. Even here indefinite number of starch grains are seen surrounding the nucleus. During later stages a slight dilation of the other end of the haustorium is also seen. Later on by dissolution of the separating membrane the two haustoria will form a single binucleate body and the two hypertrophied nuclei assume amoeboid form and begin to disintegrate as in fig. 22. At times darkly stained thread-like structures with granular depositions here and there are met with. Just as in *Sopubia* some of the endosperm cells towards the two ends are smaller and richer in protoplasmic material than the others, and help in the conduction of food material from the haustoria to the endosperm.

Summary.

(1) The reduced nucellus and thick integument are seen in both the members and the cells of the integument are rich in contents.

(2) The embryo-sac in both the forms develops from the innermost megaspore of the linear tetrad.

(3) Well developed tapetum of integumentary origin having rich cell contents and surrounding the tapering portion of the embryo-sac is seen in the two forms.

(4) The first two divisions of the primary endosperm nucleus followed by wall formation result in a row of three cells in the embryo-sac the middle one giving rise to the endosperm tissue while the other two develop into the chalazal and micropylar haustoria.

(5) While the micropylar haustoria in both are four in number uninucleate and more or less aggressive, only in *Sopubia* we find that the later stages show a massive coenocytic haustorium with four nuclei resulting from the fusion of four uninucleate ones. The micropylar haustoria in *Alonsoa* are profusely branching and with plenty of starch grains.

(6) In both there are two uninucleate chalazal haustoria which during the later stages become single and binucleate.

(7) The stages in the embryo formation are those of the typical members of Dicotyledons.

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FERTILIZATION IN *EUDORINA ELEGANS* EHRENBERG *

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Several previous workers have observed the formation of spermatozoids and egg-cells in *Eudorina*, but none of them, until quite recently, was able to observe the actual fusion of the spermatozoid with the egg-cell. The first man to observe the formation of sexual cells in *Eudorina* was H. J. Carter (1858) in some living material of the alga collected by him at Bombay. He found the spermatozoids swarming round the egg-cells, but did not see the actual process of fertilization. The formation of the antheridia and the swarming of the spermatozoids round the egg-cells were observed by several later workers [Goroschankin (1874), Merton (1908), Chatton (1911), Grove (1915), Iyengar (1933) and others], but none of them actually saw the fusion of the spermatozoid with the egg-cell. Very recently K. I. Meyer (1935) published an account of fertilization in *Eudorina monoica*, a new monoecious species from Russia. His is the first record of actual fertilization in *Eudorina*. In the same year, a few months after the publication of Meyer's paper, the author observed the actual fertilization in *Eudorina elegans* at Madras (Iyengar 1937). His observations on the mode of fertilization of *Eudorina elegans* differ very much from those of Meyer made on *E. monoica*, though his observations agree with those of Meyer as regards the details before and after the fertilization. A brief account of the author's observations is given below.

Eudorina elegans comes up practically every year in Madras in some rainwater pools formed during the Summer monsoon season (July—September) and lasts for some two to three weeks. Towards the end of its short duration every year, plenty of antheridia and egg-cells are generally formed. The author has been examining the living alga for a number of years in order to observe the actual fusion of the spermatozoid with the egg-cell. Every year he observed the profuse formation of the antheridia and the egg-cells and also the swarming of the individual spermatozoids round the egg-cells, but, until quite recently, he was not able to observe the actual fusion of the spermatozoid with the egg-cell. On 24th September 1935, he was at last fortunate enough to see the actual fertilization.

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The colonies are dioecious. About a week or so after its appearance, plenty of colonies with the gelatinous portions much swollen and expanded are found floating near the surface of the water and forming a thick frothy scum near the surface. In most of them the spermatozoids are found swarming round the egg-cells.

In a few instances the author found that the actual softening of the mucilaginous matrix of the female colony took place in the following manner. An antheridial cluster approached a somewhat quiescent female colony with well-developed large egg-cells, but with the mucilaginous envelope and matrix still quite firm as in normal vegetative colonies. The antheridial cluster soon came into contact with it by its ciliary end and kept rotating against it with a churning motion as if trying to swim its way into it. A few minutes after this churning action, the firm gelatinous outer envelope of the female colony softened very rapidly at the point of attack and soon the antheridial cluster broke up and all the individual spermatozoids of the cluster entered rapidly one by one into the interior of the female colony through the small softened spot. And very soon after this the whole of the matrix of the female colony became soft and swollen, the softening progressing gradually from the original softened spot towards the other end of the colony. In giving the above account, the writer does not, however, suggest that the softening of the female colony is brought about in this way always by the antheridial cluster. The colony, as in the case of the male colonies, generally becomes swollen quite independently.

When the gelatinous matrix of the colony gets softened, the egg-cells in the swollen female colony are seen to move slightly forward and out of their thick gelatinous walls. The discarded cell-membranes can be seen for a short time immediately behind the naked egg-cells (text-fig. 1, B), but soon become softer and indistinguishable from the remaining gelatinous portions of the colony. The eggs, after escaping from their walls, become somewhat pear-shaped and remain so for a short time (text-fig. 1, B, C, pl. II, D), but become rounded again shortly afterwards. The significance of this change of shape is not clear. Evidently, the pear shape is the first reaction of the naked protoplast after its escape from the confines of its old cell wall. At this stage the egg-cell still retains its two cilia. The two cilia of the egg-cell are placed quite well apart from each other at its anterior end (text-fig. 1, A-C).

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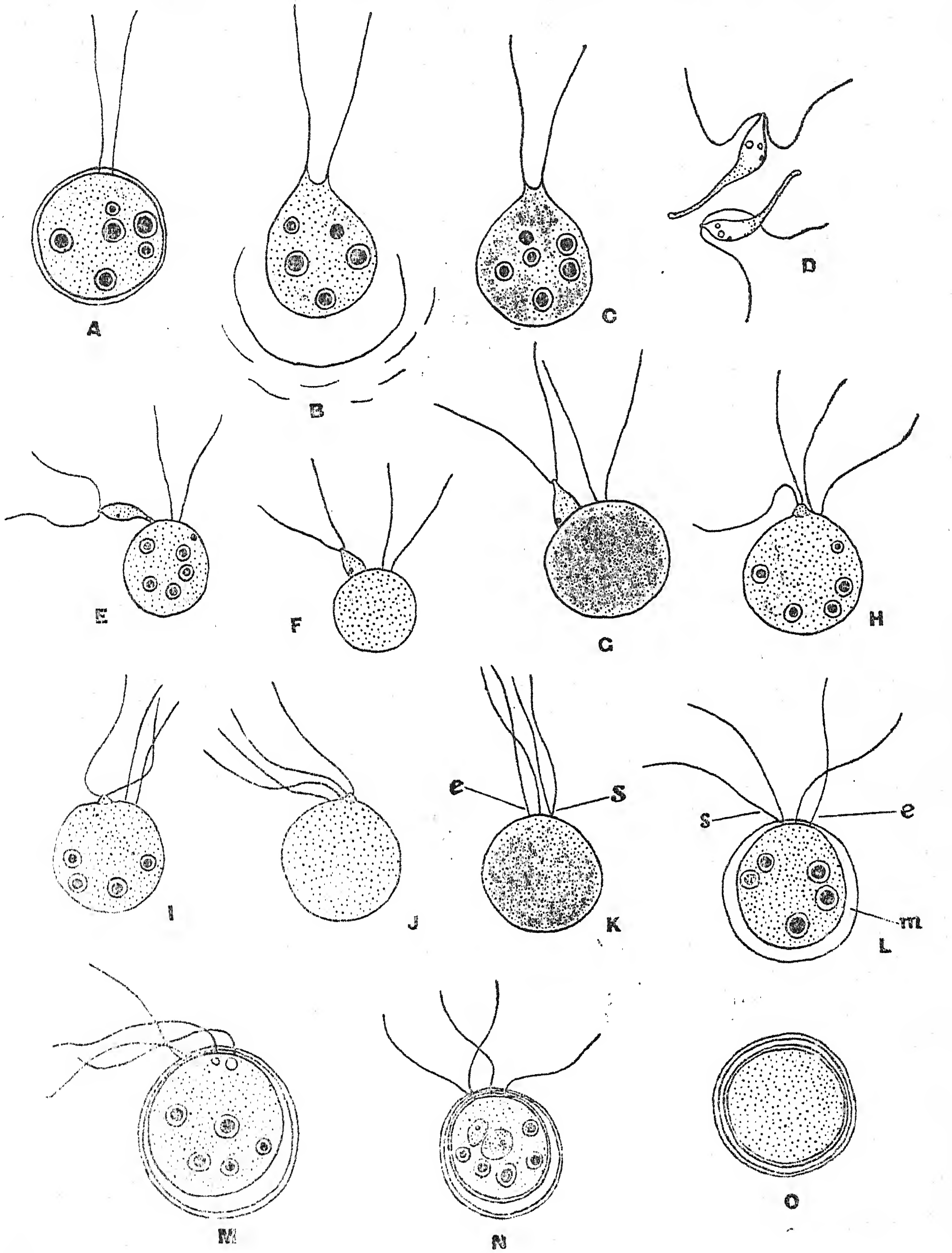
large and small nucleus belonging to the egg and spermatozoid respectively seen in the protoplast. O. Resting zygote with a wall composed of two thick, firm layers. B—G and M, drawn from living material; the rest from preserved material. *e*, cilia of the egg; *s*, cilia of the spermatozoid; *m*, mucilaginous wall. E, F, × 400; D, M, × 1100; the rest, × 870.



Text-fig. 1, A to O.—*Eudorina elegans.* A. Ripe egg-cell. B. Egg-cell with the discarded cell-membrane behind. C. Egg-cell without cell-membrane, ready for fertilization. D. Spermatozoids with two cilia, two contractile vacuoles and an eye-spot. E. Spermatozoid fusing with an egg-cell by its posterior end. F and G. Later stages of fertilization showing the gradual sinking of the spermatozoid backwards into the egg-protoplast. H, I, J. Final stages of fertilization. K. Zygote with four cilia, one pair starting close to each other and the other pair slightly apart from each other, belonging to the male and the female gamete respectively. L. Zygote with a mucilaginous wall just formed round it. M. Zygote with the outermost layer of the mucilaginous envelope having become firm and thick. N. Same as M, but with a firm inner layer secreted immediately next to the protoplast: a

The spermatozoid is narrow at the anterior end and is somewhat broader below, but becomes again gradually narrower downwards. The posterior half of the spermatozoid is extremely narrow and more or less rod-shaped. The two cilia are inserted at the anterior end a little below a small rounded beak, and are attached sideways almost at right angles to the narrow anterior end. A single eye-spot and two contractile vacuoles are seen in the anterior swollen portion (text-fig. 1, D).

The movements of the spermatozoids round the egg-cells are very varied. They get attached to the surrounding mucilage by their cilia and move backward and forward in a jerky manner, as if hammering into the egg-cells by their narrow rod-like posterior end. They frequently leave off and move to a different position and seem to browse as it were round the egg-cell with their ciliary end close to the egg. They bend their body in various ways during these movements. Finally fusion takes place. During this fusion process, the spermatozoid enters the egg-cell, not by its anterior end as one would expect, but by its narrow posterior end (text-fig. 1, E) and gradually fuses with the egg *backwards* sinking slowly into the egg-cell, the backward sinking movement of the spermatozoid evidently being helped by the actively vibratile movements of its two cilia (text-fig. 1, F-J). The spermatozoid finally sinks completely into the egg-cell, only its two cilia remaining outside (text-fig. 1, K). The fusion of the spermatozoid with the egg-cell usually takes place very close to the ciliary end of the latter.

The fertilized egg-cell possesses four cilia, two belonging to the spermatozoid and two to the egg-cell, the former pair of cilia being always very close to each other (text-fig. 1, K, L, *s*), while the latter pair remaining always slightly separate from each other (text-fig. 1, K, L, *e*). A mucilaginous wall is soon secreted round the protoplast of the zygote, but the four cilia of the zygote continue to remain still attached to the protoplast through the newly formed mucilaginous wall (text-fig. 1, L, *m.*). The outermost layer of the mucilaginous wall then becomes firmer and thicker (text-fig. 1, M, pl. II, A, C). And after some time a very thin, but fairly firm membrane is formed immediately next to the protoplast. The wall of the zygote at this time consists of three layers, an innermost thin layer immediately next to the protoplast, an outermost thick layer and a gelatinous layer between both (text-fig. 1, N). This gelatinous middle layer is not uniform in thickness. It is broadest at the posterior end and gradually becomes narrower towards the anterior end. The four cilia remain for quite a long time even after the formation of this three layered wall. The cilia are finally lost. It is not clear whether they are thrown off or withdrawn inside the protoplast. The mature zygote is always round, though a few irregularly elliptic zygotes are occasionally seen. The wall of the zygote is smooth and hyaline and consists of only two layers, a thick outer layer and a thinner inner layer, the middle mucilaginous layer being evidently used up in the thickening of the two layers. A very thin and delicate third layer is often seen outside these two thick layers.

The author in his paper on the Colonial Volvocales of South India (1933) stated that the egg-cells retained their cilia even after the softening of the general mucilaginous matrix, that the ciliated naked protoplasts of the ova were able to perform slow movements inside the general liquefied mucilage of the colony, and that the cilia were finally lost and the ova became quiescent. Meyer (1935, p. 423) confirmed most of the author's observations, but rightly pointed out that the egg-cell did not finally lose its cilia, but retained them much longer. He was the first to note the interesting facts that (1) the egg-cell retains its cilia at the time of its fusion with the spermatozoid and (2) that the fertilized egg remains four ciliated for some time after the fusion. He, however, states that the four cilia of the zygote are retained until the formation of the oospore wall. But the author's observations show that the cilia are retained for some time *even after the formation of a membrane round the zygote protoplast*, since this membrane is secreted round the protoplast without interfering with the attachment of the cilia to the protoplast.

Coming to the most important stage in the sexual reproduction, viz., the mode of fusion of the spermatozoid with the egg-cell, the author's observations differ very much from those of Meyer. Meyer's account of the fertilization is as follows. The spermatozoid after swarming round the egg-cell finally sticks to the egg-cell with its beak and clings to it with its curved side and fuses with it along its length. The boundary between the spermatozoid and the egg-cell very soon disappears and the spermatozoid is completely engulfed inside the egg-protoplast. It is at first seen like a small hump on the surface of the egg-cell and in two or three seconds nothing more remains of this hump. The flagellae of the spermatozoid however remain on the surface of the egg-cell and indicate the completed fertilization. The whole process of fertilization is very rapid and is finished within a few seconds.

The details of fusion as observed by the writer in *E. elegans* are, however, quite different. As already pointed out, he found the spermatozoid attaching itself to the egg-cell by its narrow posterior end and fusing with it *backwards*. He did not find any of the spermatozoids fusing along their length, as observed by Meyer in *E. monoica* though he watched the swarming spermatozoids for quite a long time. Again Meyer says that the process of fusion is very rapid and is finished within a few seconds. According to the author's observations, the process was not at all rapid and was not finished within a few seconds. From the commencement of the fusion up to the complete disappearance of the body of the spermatozoid into the protoplast of the egg-cell, it took at least five to six minutes. There was enough time for the author to make quickly camera lucida drawings of the fusion stages and also to show the interesting process to at least half-a-dozen students in the laboratory.

Before concluding, the author wishes to state that the process of fertilization described in this note was observed by him *only once*. He tried to confirm his first observation by observing again, if possible, further cases of actual fertilization. But unfortunately he was not able to do this, though he examined hundreds of swollen female colonies both in living and preserved material. He found in the material, however, plenty of fertilized egg-cells with 4 cilia. Six months later, in March 1936, he came across some living *Eudorina elegans* again. But even here he did not succeed in seeing the actual process of fertilization, though he found plenty of fertilized egg-cells with four cilia as before. But, while examining later on some preserved material of the alga collected in March 1936, he came across a single colony in which three egg-cells were in the last stage of fertilization, while all the remaining ones had already been fertilized. In each of these three egg-cells undergoing fertilization, the anterior end of the spermatozoid was seen as a small conical projection bearing the cilia (text-fig. 1, H, I, J, and pl. II, B).

Since the process of fertilization was actually observed by the author only once and since the method of fusion of this spermatozoid *backwards* with the egg-cell is so very unusual and moreover so very different from what Meyer found in *E. monoica*, the author hesitated for a long time before publishing the above account of fertilization in *E. elegans*. As he did not succeed in seeing the actual fertilization again even after repeated examination of several collections of living and preserved material, he finally decided to publish this account in the hope that other workers may watch for the fertilization stages of *E. elegans* and confirm or refute the correctness of the author's account based on his observation of a single case of actual fertilization and a single preserved colony showing fertilization stages.

Postscript.

Since writing this note, the author was glad to see in the Agenda of the Meeting of the Linnean Society of London, dated the 7th January 1937, a short abstract of a paper by Dr. M. A. Pocock on fertilization in some South African material of *Eudorina elegans*. The abstract runs as follows:—

> "Ultimately the apex of the spermatozoid fuses with that of the egg; fusion proceeds rapidly backwards until the body of the spermatozoid has entirely disappeared into the

egg. The two male and the two female flagella (of nearly equal length) continue to move gently for some time, so that the zygotes are easily distinguished from the unfertilized eggs. Eventually a wall is formed and the resting zygospore matures."

Since she states in this abstract that "the apex of the spermatozoid fuses with that of the egg", her observations on the fertilization in *Eudorina elegans* would appear to agree more with those of Meyer than with those of the author. But, in the absence of her full paper, it is not possible to make any further comparisons or comments. Her paper is awaited with interest.

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Explanation of plate II

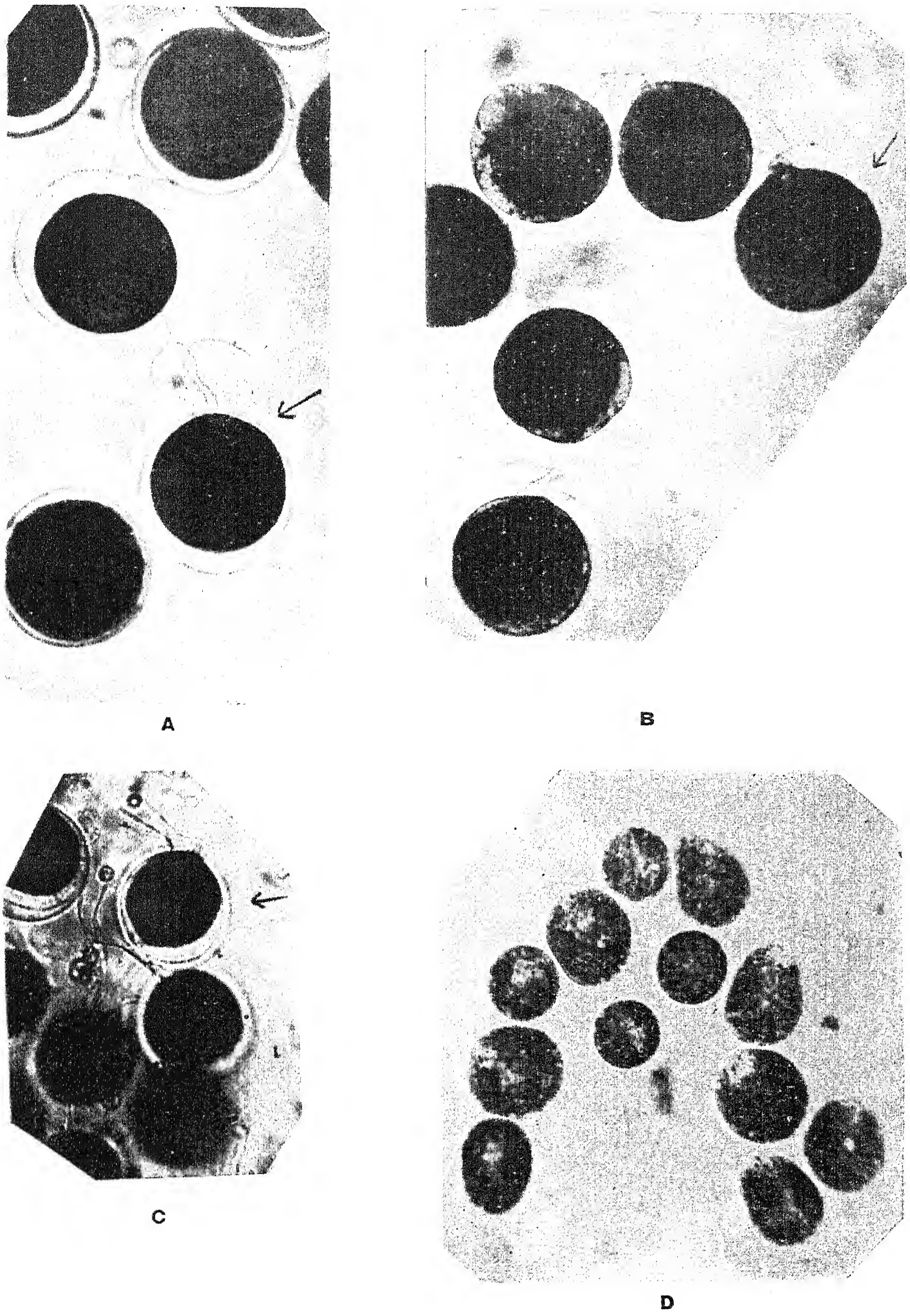
Eudorina elegans.

(A) Photomicrographs of zygotes. Arrow points to a zygote with four cilia. Note the mucilaginous wall round the zygote with the outermost layer thickened. × 1100.

(B) Zygotes during and immediately after fertilization. Arrow points to a zygote in the last stage of fertilization, with the spermatozoid almost completely sunk into the egg-cell, only its extreme anterior end being still visible as a conical projection outside. Another zygote below shows four cilia. The mucilaginous wall is not yet formed round the zygote protoplast. × 1100.

(C) Same as A. × 750.

(D) Egg-cells which have become pear-shaped after throwing off their cell-membranes. Eye-spots are seen in a number of them. × 600.



M. O. P. IYENGAR—*EUDORINA ELEGANS* EHRB.

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CYTOLOGY-STUDY OF BASIDIA OF POLYPORACEAE

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Earlier cytological observations were confined to the determination of the presence or absence of nuclei in the basidia of Hymenomycetes. Strasburger (in 1884) stated that nuclei existed in the cells of several of the Agaricinæ and that the young basidium contained a single nucleus, which divided into two at the time when the sterigmata began to form, and then further divided until as many as eight might be observed in the basidium. (In 1886) Rosenvinge after examination of thirty-five species of Hymenomycetes found only a single nucleus in the young basidia. He got indication of the indirect division of the nucleus but was not able to make out any details of the division. It was Wager who from (1891-99) gave us the basis for most of our present day conceptions of the nuclear phenomenon in the basidium. He pointed out that not only did the nucleus of basidium possess a structure closely resembling that of the higher plants, such as, chromatin, linin, differentially stained nucleolus, nuclear membranes, etc., but that the nuclear division more nearly resembled that of the latter, inasmuch as a distinct equatorial plate, and apparently a spindle-figure, were produced. Wager, however, could not make out how the spindle was formed. Dangeard (in 1895) was the first to establish the fact that only two nuclei fused to form the secondary nucleus in the basidium of *Polyporus versicolor*. He was the first also to affirm the sexual nature of this nuclear fusion in the basidium, which he regarded as essentially equivalent to the sexuality of the higher animals and plants. Juel (in 1897) found astral rays and centrosomes in connection with the nuclear division in the basidium and counted the number of chromosomes as varying from six to eight. René Maire (in 1902) described the process of nuclear division in the basidia of a number of forms and gave good figures of centrosomes, polar asters, etc. He first observed the appearance of cytoplasmic threads connecting the nuclei and the sterigmata at the four-nucleated stage of the basidia and held that the nuclei moved into the sterigmata by the contraction of the threads and thus finally reached the spores. The observations of Wager, Juel and Maire as to the appearance of the spindles, astral rays, centrosomes, etc., were confirmed in the main by Ruhland (in 1901) in a number of Basidiomycetes. Levine (in 1913) carried out cytology-study of the basidia of three species of Polypores; the basidia were all binucleated, the two nuclei fused in all cases and the resulting nucleus divided twice, forming four nuclei and the reduction of the chromosome-number took place in the first division. These four nuclei migrated to the spores and there divided again. (In 1927) Kühner as a result of the cytology-study of the hymenium of *Mycena galericulata* (bisporic form) could not find any "nebenkern" at the summit of the basidia nor any fibrillar threads stretching out of the nuclei. He has given a number of good figures of the different stages of the nuclear division but he could not count exactly the number of chromosomes, which according to him were certainly more than two, and probably varied from six to twelve. Vokes (in 1931) held that in case of *Coprinus atramentarius* four hyaline bodies remained attached to the apex of the cell-wall of the basidium from the time the fusion-nucleus came in contact with it until after the formation of spores. These bodies reacted on both the wall and the nucleus in such a way that the wall pushed up at their points of contact and sterigmata were formed. The nucleus then followed, and after it had entered the spore the wall greatly enlarged and assumed mature proportions. After the hyaline bodies became attached, they remained at all times at the apex. After a sterigma formed, a hyaline body was at the tip as well as after the spore was formed. He counted eight chromosomes in the fusion-nucleus, reduction apparently taking place in the first division. (In 1932) Wakayama working on some members of Polyporaceae found the nuclear phenomena in the basidia as fundamentally equivalent to meiosis in higher plants. He held that the spindle was intranuclear, that a centrosome was found at each pole and that the direction of the long axis of the spindle had no taxonomic value. The number of chromosomes varied from two to six according to the species he examined.

Till now only a few Polypores have been studied cytologically, probably on account of the extreme smallness of their hymenial elements and of the nuclei and constituent chromosomes. In the present case basidia of eleven species of Polyparaceæ—*Polyporus adustus, P. squamosus, P. betulina, P. brumalis, P. rutilans, Polystictus versicolor, Polyst. sanguineus, Polyst. abietinus, Fomes ribis, Merulius (Phlebia) radiata,* and *Boletus luridus* along with four *Agarics* were studied cytologically; not only had the nuclear division in the basidia been followed, but also the mitochondria and the vacuolar bodies in them had been studied. Bouin's fluid, Fleming's strong and weak solutions and Regaud's fluid were used as fixatives. Regaud's fluid was good for fixing the mitochondria. Paraffin sections usually 5μ thick were cut and were stained with Heidenhain's Iron-haematoxylin. In some cases Breinl's stain was employed and basidia of *Ganoderma lucidus* were stained with Feulgen's stain. The tramal hyphae, subhymenia and basidia were found to be regularly binucleate. The two nuclei in the basidium coming into contact with each other, gradually fused into one large fusion-nucleus with two prominent nucleoli. In the prophase stage of the fusion-nucleus synapsis was distinct in some cases, the fusion-nucleus thus passed through two quick divisions—usually first meiosis and then mitosis, the basidium ultimately became tetranucleate. By this time four sterigmata were formed at the apex of the basidium and each of the four nuclei was seen migrating constricted through the narrow arm of the sterigma and they ultimately formed the nuclei of the terminal spores.

I now proceed to describe briefly each species separately:—

Polyporus adustus (Willd.) Fr.

PLATE III

Sporophore of *Polyporus adustus* was fixed in Regaud's fluid and 5μ sections were stained with Iron-haematoxylin. Binucleated basidia, anaphase of the fusion-nucleus and basidiospores with two nuclei were observed (Figs. 1-3).

Polyporus squamosus (Huds.) Fr.

PLATE III

Sporophore of *Polyporus squamosus* was fixed in Bouin, Regaud and Flemming's strong and weak solutions. With Regaud's fluid mitochondria were very prominent in 2-3μ sections of basidia (Fig. 4). With Flemming's weak solution in binucleated basidia the two nuclei were observed in the act of fusion, the fusion-nucleus had two nucleoli and in the prophase stage of the enlarged fusion-nucleus the chromatic filaments of the spirem were well spread out (Figs. 5-7). With Flemming's strong solution metaphase stage of both the first and the second divisions of the fusion-nucleus was observed in the basidia, the spindle was transverse in each case (Fig. 9). In one basidium the telophase stage of the fusion-nucleus was noticed (Fig. 8). In all cases Iron-haematoxylin was used as stain with occasional Breinl's stain.

***Polyporus betulina* Fr.**

PLATE IV

Sporophore of *Polyporus betulina* was fixed in Regaud's fluid, paraffin sections were cut 8μ and stained with Iron-haematoxylin. Tramal hyphae and subhymenium were binucleated, mitochondria (cystosomes) were well-stained and visible, in some cases long filamentous bodies like plasts were noticed and big vacuoles (Figs. 10-13). Young basidia with two nuclei, one fusion-nucleus and ultimate division into four smaller nuclei (Figs. 14 and 15) were observed, and in one basidium sterigmata showed the presence of smaller nuclei in them (Fig. 16).

***Polyporus brumalis* (Pers.) Fr.**

PLATE V

Sporophore of *Polyporus brumalis* was fixed in Flemming's weak solution and 10μ sections were stained with Heidenhain's Iron-haematoxylin. Basidia were binucleated, the two nuclei were seen in contact with each other in a state of fusion, the prophase of the fusion-nucleus was distinct and some of the resulting nuclei at the top of the basidium were seen connected with fibrils extending into the sterigmata just prior to migration through the narrow arms of the sterigmata (Figs. 17-21).

***Polyporus rutilans* (Pers.) Fr.**

PLATE V

Sporophore of *Polyporus rutilans* was fixed in Flemming's strong solution and 3μ sections were stained with Iron-haematoxylin. Prophase, anaphase and telophase of the fusion-nucleus of the basidium were observed (Figs. 22-25), the spindle was transverse and older basidia had nuclei either at the base of the sterigmata or within them (Figs. 26 and 27).

***Polystictus versicolor* (Linn.) Fr.**

PLATE VI

Sporophore of *Polystictus versicolor* was fixed in Regaud's and Bouin's fluids, paraffin sections were cut 5μ and stained with Heidenhain's Iron-haematoxylin. With Regaud's fluid in the tramal hyphae which were binucleated (Fig. 28) mitochondrial bodies were very prominent, some of them looked like plasts and a number of vacuoles were observed. And there was a number of dead double-walled hyphae in which the cytoplasm was agglutinated in the form of a narrow median strand (Fig. 29). With Bouin the fusion-nucleus of the basidium was noticed at the synapsis stage of the prophase (Fig. 30) and the anaphase of first division of the fusion-nucleus (Fig. 31) was observed. The spindle was transverse and apical. The nucleus of the spore at the end of the sterigma passed through synapsis and ultimately divided into two (Figs. 32 and 33).

Polystictus sanguineus **Linn.**

PLATE VI

Sporophore of *Polystictus sanguineus* was fixed in Flemming's strong solution and 4μ sections were stained with Iron-haematoxylin. Prophase with well-spread out chromatic filaments and telophase in the first division of the fusion-nucleus in the basidia were observed (Figs. 34-36).

Polystictus abietinus **Fr.**

PLATE VI

Sporophore of *Polystictus abietinus* was fixed in Regaud's fluid and 5μ sections were stained as above. Basidia were regular with a number of prominent encrusted cystidia (Fig. 37) at intervals; in one basidium the telophase stage of the fusion-nucleus was distinct (Fig. 38) and the plane of division was longitudinal.

Fomes ribis **(Schum.) Fr.**

PLATE VII

Sporophore of *Fomes ribis* was fixed in Bouin's fluid and 5μ sections were stained with Iron-haematoxylin. Two nuclei (with one nucleolus in each) in the younger basidium were observed in contact with each other prior to fusion and the large fusion-nucleus in the prophase stage had the chromatic filaments in the form of a clear net with one elongated fused nucleolus in some basidia (Figs. 39-41). Subsequently, the fusion-nucleus passed through early anaphase in the first division (Fig. 42).

Merulius (Phlebia) radiata **Fr.**

PLATE VII

Sporophore of *Merulius radiata* was fixed in Regaud's fluid and 5μ sections were stained with Iron-haematoxylin. Basidia with the prophase of the fusion-nucleus and the ultimate division into four smaller nuclei were observed (Figs. 43-45) and spores were with two nuclei (Fig. 46).

Boletus luridus **(Schf.) Fr.**

PLATES VII AND VIII

Fruit-body of *Boletus luridus* was fixed in Bouin's and Regaud's fluids and 2μ sections were stained with Iron-haematoxylin. With Regaud's fluid mitochondria in the basidia were very distinct and basidia were regular in series with a number of projecting cystidia (Figs. 47-49). With Bouin's fluid the binucleated basidia and the fusion-nucleus in the basidium undergoing prophase and metaphase were observed (Figs. 50 and 51), the spindle was oblique and almost perpendicular.

Thus, the process of nuclear division in all its stages has been followed, though not in one single species. It corresponds fundamentally to the reduction-division in higher plants. But the number of chromosomes could not be satisfactorily counted as they were extraordinarily small. In some cases the nucleus of the spore divided into two by way of mitosis, spores thus becoming binucleate (Figs. 3, 33 and 46). In none of my preparations could I find any distinct centrosome or hyaline bodies at the apex of the basidia, nor any fibrillar threads connecting the nuclei to the centrosomes as noted by Levine and Vokes; I could get only fibrillar threads extending from the nuclei in the basidium to the sterigmata (plate V, Fig. 21) just prior to their ascent in *Polyporus brumalis*. The long axis of spindle was usually transverse to the basidia, but in some cases the spindle was found in an oblique and almost longitudinal plane. Vokes and Wakayama also hold that the long axis of the spindle has no definite orientation in either division, and hence the direction of the long axis can have no taxonomic value. This opinion has also recently been expressed by Miss Wakefield and others at the International Botanical Congress at Amsterdam in 1935. The greater part of this work was done at the Sorbonne, Laboratoire de Botanique de Prof. P. A. Dangeard (of Paris University), to whom I am obliged for constant help and laboratory-facilities.

In microtome sections, 2-3μ thick, with Regaud's fixative minute mitochondrial bodies came out very clearly in the basidia of Polypores (Figs. 4, 10, 11 and 48), but very few plasts, however, were visible. The vacuolar bodies within the basidia of some common Polypores were studied with the help of special methods of Golgi, Kolatchev, Bensley, Weigel, etc., the control-method of vital staining with neutral red was carried out. To me it seems that the vacuolar bodies in the basidia of Polypores correspond to Golgi-bodies so often described by Gatenby in animal cells and that the solid Golgi-elements are nothing but artifacts due to the excessive precipitation of metallic silver or osmium inside the vacuoles, as observed by me (in 1931) in 'Animals of Botany'. A preliminary account of the 'nebenkern' and the Golgi material in *Coprinus sterquilinus* by J. E. Sass (1934) does not seem to be very convincing, as there was no control-experiment of vital staining and the results figured in his plate could be obtained, according to the author's admission, with only a few out of the several fruit-bodies examined. Vokes's and Kühner's works also do not show any "nebenkern" or Golgi material by the side of the fusion-nucleus in any of the basidia. With Feulgen reaction the nucleolus of the fusion-nucleus in the basidium of *Ganoderma lucidus* remained unstained while the chromatin-threads took on purplish red colour; this shows that the nucleolus here is not a mass of chromatin. Saksena (1936) obtained almost the same result with the nucleolus of the resting nucleus in two species of *Pythium*.

The importance of the basidium has been recently stressed by Rogers (1934) in the phylogenetic classification of the Basidiomycetes. Nobles (1935) has studied the cytology of the conidiophore in *Peniophora Allescheri* where he has found that in clamp-bearing mycelium the conidiophore is at first binucleate, but these two nuclei divide simultaneously without any clamp-connection, ultimately giving rise to four, eight, sixteen or more nuclei at the end, half of which go to form the nuclei of the terminal conidia of one sex on one side, and half the nuclei of the conidia of the other sex on the opposite side; there is no nuclear fusion followed by the reduction division as in the basidium. In *Ganoderma lucidus* and *G applanatus* towards the end of the rainy season I (1935) examined cytologically the mode of formation of secondary basidiospores at the end of tramal hyphae-projections within the pore-tubes, which seem to take on the function and the position of the basidia to a certain extent. These tramal hyphae-projections were binucleate, the two nuclei in the hyphae gradually fused into one fusion-nucleus which by amitosis gave rise to the nucleus of the terminal secondary spore. Thus, though here we have nuclear fusion there is no meiosis as with the fusion-nucleus of the basidum. Basidium and conidiophore, therefore, seem to differ greatly cytologically. This view is also shared by prominent cytologists (Gwynne Vaughan, Dangeard, etc.) and Bessey (1935, p. 309) and Hiley (1919, p. 105) who hold that the nuclei which enter the conidia are not derived at all directly from a fusion-nucleus.

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All the figures were drawn with the aid of Zeiss camera lucida and with Zeiss 2mm. apochromatic objective (N. A. 1.40) and aplanatic condenser (1.4) combined with Zeiss compensating oculars 15X and 20X. Figs. 1-3, 8-13, 15 and 16, 22-36, 43-46 were drawn with ocular 20X; the distance from the camera-mirror to the drawing board was 280mm. and the draw-tube of the microscope was always kept at 170mm. of the scale. Figs. 4-7, 17-21, 39-42 and 48 were drawn with ocular 15X; the distance from the camera-mirror to the drawing board was 280mm. as above. Figs. 47, 50 and 51 were drawn with ocular 20X; the distance from the camera-mirror to the drawing board was 145mm. Figs. 14, 37 and 38, 49 were drawn with ocular 15X, the distance from the camera-mirror to the drawing board was 145mm. as above. For these drawings I am greatly indebted to my former Demonstrator Mr. Mriganko Bhusan Bose, M.Sc.

EXPLANATION OF PLATES III—VIII

PLATE III

Polyporus adustus

Fig. 1. Basidia with 2 nuclei.
Fig. 2. Anaphase of the fusion-nucleus.
Fig. 3. Basidiospore with 2 nuclei.
Fig. 4. Mitochondria very prominent in basidium.
Fig. 5. Two nuclei in act of fusion in the basidium.

Polyporus squamosus

Fig. 6. Fusion-nucleus with two nucleoli.
Fig. 7. Prophase of the fusion-nucleus with well spread out-chromatic filaments.
Fig. 8. Telophase of the fusion-nucleus.
Fig. 9. Metaphase of the first and the second divisions of the fusion-nucleus.

PLATE IV

Polyporus betulina

Fig. 10. Tramal hyphae with mitochondria and plasts-like bodies.
Fig. 11. Tramal hyphae with mitochondria and big vacuole.
Fig. 12. Subhymenial cell with mitochondria and nucleus.
Fig. 13. Subhymenial cell with two nuclei.
Fig. 14. Basidia showing one fusion-nucleus, division into 2 nuclei and into 4 smaller nuclei.
Fig. 15. Basidium with 2 divided nuclei.
Fig. 16. Basidium with sterigmata showing the presence in them of smaller nuclei on way to spores.

PLATE V

Polyporus brumalis

Fig. 17. Binucleated younger basidium.
Fig. 18. Basidium with 2 nuclei in contact with each other.
Fig. 19. Primary nuclei in basidium.
Fig. 20. Prophase of the fusion-nucleus in the basidium.
Fig. 21. Two of the nuclei at the top of the basidium connected with fibrils extending into two sterigmata.

Polyporus rutilans

Fig. 22. Prophase of the fusion-nucleus.
Fig. 23. Anaphase of the fusion-nucleus.
Fig. 24. Telophase of the fusion-nucleus.
Fig. 25. Two resulting nuclei of the first division.
Fig. 26. Nuclei at the bases of the sterigmata.
Fig. 27. Nucleus within a sterigma.

PLATE VI

Polystictus versicolor

Fig. 28. Binucleated tramal hypha with mitochondria, plasts-like bodies and a number of vacuoles.
Fig. 29. Dead double-walled tramal hypha with cytoplasm agglutinated.
Fig. 30. Synapsis of the fusion-nucleus in the basidium.
Fig. 31. Anaphase of the first division of the fusion-nucleus.
Fig. 32. Synapsis of the nucleus of the spore.
Fig. 33. Basidiospore with 2 nuclei.

Polystictus sanguineus

Fig. 34. Younger basidium.
Fig. 35. Prophase of the fusion-nucleus with well spread out chromatic filaments.
Fig. 36. Telophase in the first division of the fusion-nucleus.

Polystictus abietinus

Fig. 37. Basidia with a number of encrusted cystidia.
Fig. 38. Telophase of the fusion-nucleus in the basidium with spindle longitudinal. ,

PLATE VII

Fomes ribis

Fig. 39. Two nuclei (with one nucleolus in each) in contact with each other in younger basidium.
Fig. 40. Prophase of the fusion-nucleus with spread out-chromatic filaments.
Fig. 41. Fusion-nucleus with an elongated fused nucleolus at the apex of the basidium.
Fig. 42. Early anaphase and telophase of the second division of the fusion-nucleus in the basidium with spindle oblique

Merulius (Phlebia) radiata

Fig. 43. Prophase of the fusion-nucleus in the basidium.
Fig. 44. Basidium with 4 divided nuclei towards the top and plasts-like bodies near the centre.
Fig. 45. Four divided nuclei towards the base of a basidium.
Fig. 46. Basidiospore with 2 nuclei.

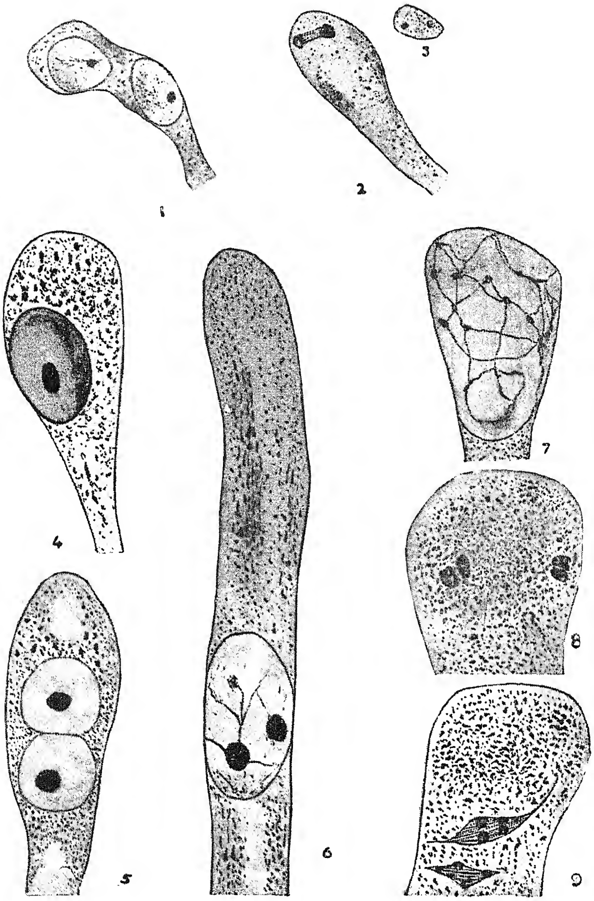
Boletus luridus

Fig. 47. Basidia with projecting cystidium.

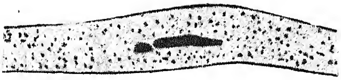
PLATE VIII

Boletus luridus

Fig. 48. Prominent mitochondria in the basidium.
Fig. 49. A portion of the hymenium showing a group of basidia with projecting cystidia; some of the basidia were binucleated while others showed one fusion-nucleus in the prophase stage.
Fig. 50. Prophase of the fusion-nucleus in a basidium.
Fig. 51. Metaphase of the fusion-nucleus in the basidium with spindle oblique.



S. R. BOSE—*BASIDIA OF POLYPORACEAE*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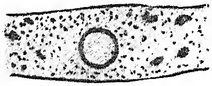
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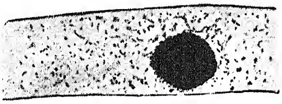
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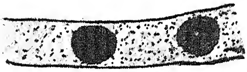
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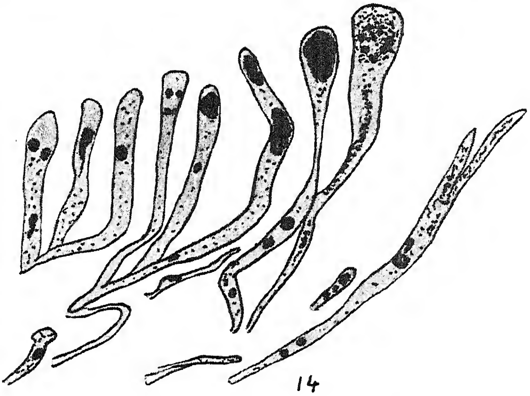
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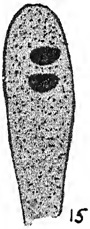
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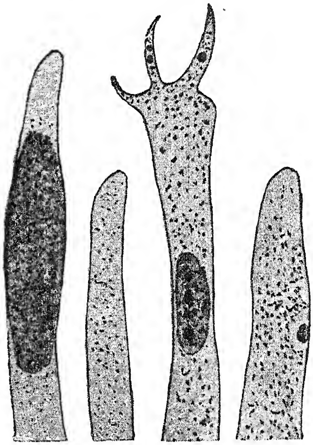
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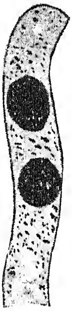
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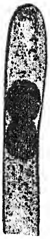
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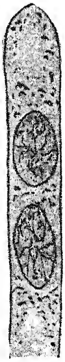
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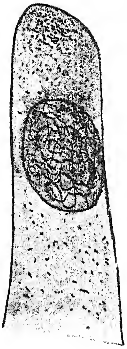
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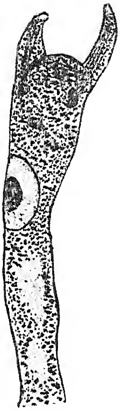
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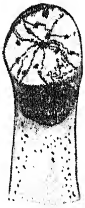
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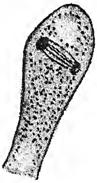
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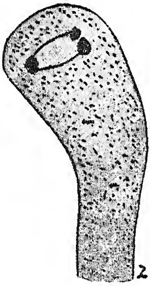
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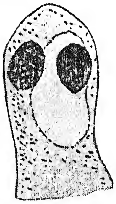
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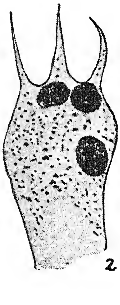
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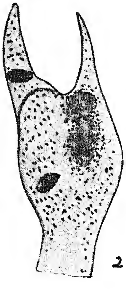
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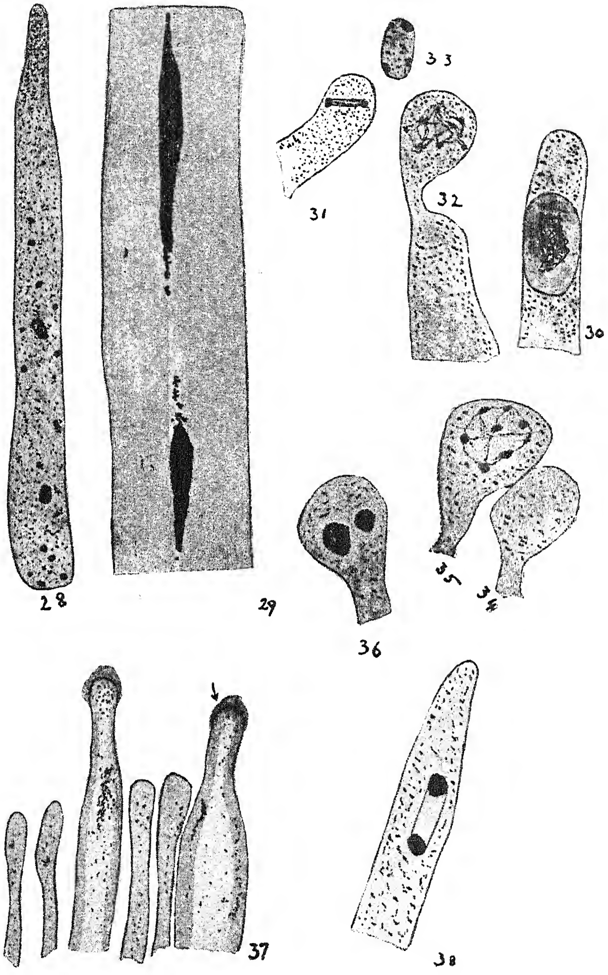
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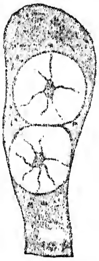

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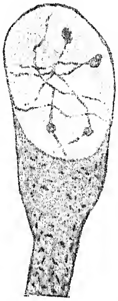

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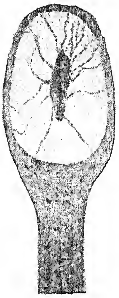

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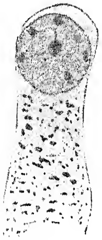

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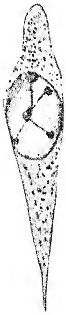

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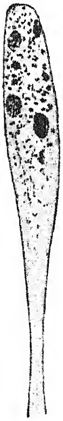

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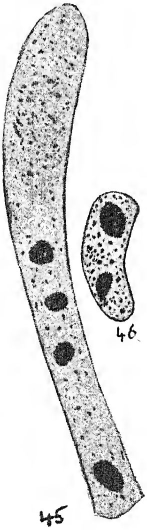

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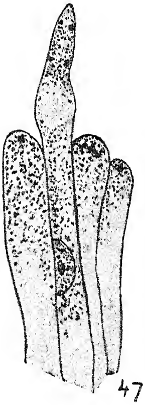

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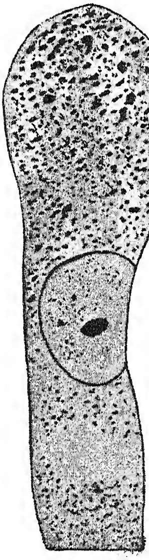

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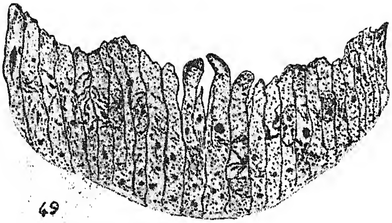

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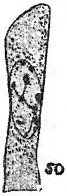

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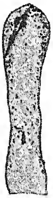

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S. R. BOSE—*BASIDIA OF POLYPORACEAE*

INVESTIGATION OF THE PHYSIOLOGICAL AND CHEMICAL CHANGES ACCOMPANYING VIVIPAROUS GERMINATION IN MANGO

BY

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Introduction

Viviparous germination in angiospermic plants, though not quite uncommon, is still a rare phenomenon. Its most striking example is offered by the mangroves in which the seedling extends its hypocotyl to a length of as much as 18″ before it falls from the tree. This has given rise to a variety of speculations from time to time but has lacked proper analysis for want of experimental proof. The difficulty of obtaining the right sort of material at the required moment has frequently stood in the way of direct experimentation.

An opportunity of obtaining such a material was provided while engaged in a detailed programme of work undertaken to investigate the physiology and chemistry of mango fruits under storage and orchard conditions. One of the local varieties of mango in the experimental orchard showed an unusual number of viviparous fruits and the seedling (Plate IX) had attained a length of 1—7″ at various stages of germination (Plate X). The discovery of such a material provided the stimulus to compare certain physiological and chemical changes in the various parts of normal as well as viviparous mango which forms the subject matter of this communication. Some of the comparative observations of normal and viviparous fruits necessitated the performance of experiments on germination of mango under controlled conditions of environment.

Methods

Normal as well as viviparous mangoes (*deshi* variety) gathered from the tree at different heights were separated into the epicarp, the mesocarp, the endocarp and the seed. Determinations of temperature, water content, H-ion concentration, respiration, carbohydrates and total nitrogen were made separately on each sample of mesocarp and of seed. Ten such samples were analysed in each case and the average taken into consideration.

Fruit temperature was measured by the thermo-couple method described elsewhere by one of us (Singh 1924; Cf. also Miller 1931). For the determination of water content the material was weighed and incubated to constant weight at 100°C. pH was determined by the electrical method depending upon the use of the quin-hydrone electrode. Use was made of Singh and Mathur's (1936) gas analysis apparatus for the measurement of CO_2 output.

Estimation of sugars was made on the fresh weight basis by Benedict's method. For starch, the residue of the material after alcoholic extraction was dried, weighed and powdered to a fine state. It was then boiled with 500 to 600 c.c. of distilled water to gelatinize starch, and cooled to 37°C. with the addition of 0.05 gm. of solid taka-diastase and incubated again at 38°C., care being taken to stir the solution at times with addition of a drop of toluene every 5—6 hours in order to avoid fungus growth. After complete hydrolysis of starch, as tested by the iodine reaction, the liquid was decanted the residue repeatedly squeezed, moistened and pressed till no liquid was found adhering to it. The solution together with the washings was boiled in order to kill taka-diastase, finally prepared after clarification in the usual manner and titrated against Benedict's solution. Total nitrogen was estimated by the modified Kjeldahl's method to include both the organic and the inorganic nitrogen.

Observations and their interpretation

CONDITION OF THE MESOCARP

Physiological condition: On reference to table I it is seen that the CO_2 output from the mesocarp of the viviparous fruit is lower than that of the normal fruit. The pH of the mesocarp is less in the viviparous fruit than that in the normal fruit, which would mean that the mesocarp of the former is more acidic in nature than the mesocarp of the latter. In other words, the seed in the viviparous fruit lies in a more acidic medium. In an earlier contribution (1935) from this Station it has been shown that the germination and early growth of sugarcane is greatly accelerated by previously soaking the cane-setts in solutions of varying H-ion concentration. Crocker and Davis (1914) have shown that the effect of acids on the germination of *Alisma plantago* is largely attributable to the hydrolysis of the pectic substances of which the coat almost entirely consists. The seed-coat thus weakens so that the imbibitional and osmotic swelling of the embryo is capable of breaking away the coat-cap at the larger end of the embryo. According to the same authors acids are also partly effective in increasing the imbibitional and osmotic swelling of the embryo. It may be that a similar reaction, besides affecting the embryo, alters the composition of the endocarp in this variety of mango. In nature perhaps the walls may gradually be affected by bacterial action in the soil or by acids produced in decay.

The moisture percentage is higher in the normal fruit than in the viviparous. This decrease in the latter may be due either to surface evaporation of water through fruit epicarp or to absorption of water by the endocarp and the seed. The latter possibility finds its justification in view of the simultaneous increased water content of the seed in the viviparous fruit over the control fruit (Table IV).

Composition: The reducing sugars (Table II) occur in higher concentration in the viviparous fruit than in the normal one; the non-reducing sugars and the starch at the same time being present in lower concentration in the former than in the latter. The percentage of total nitrogen too is lower in the viviparous fruit than in the normal one. From a consideration of these differences between the chemical composition of the normal and the viviparous fruit it appears that in the latter the general tendency seems to be towards a breakdown of reserve substances in the mesocarp which normally does not take place in normal fruits.

TABLE I

Respiration, pH value, temperature and moisture content of the mesocarp*

Item	Normal fruit	Viviparous fruit.
Respiration (CO_2 in mgm. per gram dry weight per hour)	0·28	0·11
pH value	6·4	5·8
Temperature	34°C.	31°C
Moisture content %	74·81	60·67

TABLE II

The composition of the mesocarp*

Item	Normal fruit	Viviparous fruit
Reducing Sugar %	2·09	2·12
Non-reducing Sugar%	10·05	8·25
Starch%	2·05	1·95
Total nitrogen%	0·14	0·08
C/N	14·6	24·3

ENDOCARP AND SEED CONDITION

Failure of immediate germination of many seeds usually in nature, even when to all appearances placed in optimum germination conditions, is often traced to certain characteristics of the seed or of fruit coat or the embryo. Immediate germination on the other hand, would mean that in addition to the external factors being favourable the internal conditions of the seed may also have been favourable for germination. Interest therefore centres round the problem: what are the changes accompanying germination on the parent tree and what stimulates these?

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* The values represent averages of 10 observations in each case.

Endocarp condition: The endocarp, inside the viviparous fruit, is found invariably split at its broader end overlying the funicular attachment of the testa which condition is, however, found to be absent inside the normal fruit. In the mangroves where viviparous germination is a normal feature the integuments are either reduced or absent. Working on the influence of CO_2 on the dormancy of seeds of *Brassica alba,* Kidd (1914, 1917), and Kidd and West (1920) suggest that the immediate germination or rather the continuous development of the embryo is due to the absence of autonarcosis by the respiratory CO_2, which this condition of the integument permits. In order to test whether the split in the endocarp—since the seed-coat itself is very thin to offer any obstruction to the extrusion of the radicle—facilitates germination, healthy fruits of mango were plucked from the tree and their epicarp and mesocarp layers were completely removed. The endocarps with the seeds inside were then separated into three lots; (i) with intact endocarp; (ii) with endocarp slightly broken at the top and (iii) with endocarp completely removed taking care that no injury was done to the seed inside. Such separate lots of seeds were then germinated under strictly similar conditions of soil and of atmosphere. Their germination percentage as calculated from time to time is given in Table III.

TABLE III

Germination percentage

Days after sowing.	Endocarp intact.	Endocarp slightly broken.	Endocarp removed.
15	4	20	12
20	16	60	40
25	16	72	68
30	28	72	76

From the above table it will be seen that the seeds enclosed within slightly broken endocarp (as found in viviparous fruit) germinate earlier than the seeds either within the intact endocarp (as exists in normal fruits) or those completely without it. The delayed germination in the case of the seed within intact endocarp may be due to the resistance offered by the latter for some time. The seeds without endocarp sooner or later make up for this germination and the percentage equals that of seeds with slightly broken endocarp. On the basis of these results it may be said that the endocarp, since it is intact in the normal fruit, offers some resistance to the germination of the seed inside it while the same being split in the viviparous fruit does not obstruct germination. Crocker and Davis (1914) and Ewart (1908) have found almost similar results that seeds of aquatic plants, after breaking or removing the seed-coats, and of *Sagittaria* after abrasion with sand paper respectively, germinated readily.

TABLE IV

Respiration, pH value, temperature and moisture content of the seed*

Item	Normal fruit		Viviparous fruit	
	Cotyl	Plumule and radicle	Cotyl	Plumule and radicle
Respiration (CO_2 in mgm. per gram dry weight per hour) ..	0·0981	0·101	0·12	0·24
pH value ..	5·0	5·0	4·6	4·4
Temperature ..	33·4°C	..	36·4°C	..
Moisture content % ..	27·28	29·21	30·32	32·45

Physiological condition of the seed: The CO_2 output (Table IV) of the seed in the viviparous fruit is found to be decidedly more than in the normal fruit. The plumule and radicle together, as a rule, shows higher respiration than the cotyledons in both the kinds of fruits but in the viviparous condition it respires much more than in the normal state. This gives an indication of the more vigorous condition of the plumule and radicle in particular and of the seed in general with its viviparous germination. Temperature and moisture content in the viviparous fruit are higher than in the normal. Increased temperature of the seed may be due partly to the internal temperature already prevailing in the mesocarp (viviparous fruit) and partly to the heat generated in the respiration of the cells of the seeds. Increased moisture content suggests that the seed has absorbed water from the mesocarp and in view of the split condition of the endocarp, the absorption of water which would be under check is facilitated. Since high temperature and increased moisture content are two factors which especially stimulate respiration and since in so doing self-heating of the seed takes place which may raise the temperature to a point where other chemical reactions may occur, as shown by

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* The values represent averages of 10 observations in each case.

Gore (1911), it may be that increased respiration and high temperature as found in the viviparous fruit are interdependent and these accompanied with higher moisture content might have stimulated chemical reactions which accompany viviparous germination.

Another point of interest is that the effective acidity in the cotyledons and the plumule and radicle in the viviparous fruit (Table IV) increases in contrast to that in the normal fruit. Increase in acidity may be attributable to the acidic medium of the mesocarp. Eckerson (1913) found a similar increase in acidity in seeds of *Crataegus* during after-ripening which was correlated with increased water holding power and increased activity of catalase and peroxidase. Some similar function might be suggested for the increased acidity of the mango seed during viviparous germination with which an increased absorption of water by the seed and increased respiration of the same are found to be associated. Rose (1919) also showed that seeds of *Tilia americana* develop acidity during after-ripening.

TABLE V

The composition of the seed*

Item	Normal fruit		Viviparous fruit	
	Cotyl	Plumule and radicle	Cotyl	Plumule and radicle
Reducing sugar % ..	0·56	0·48	0·589	2·12
Non-reducing sugar % ..	1·27	1·23	1·19	1·01
Starch % ..	3·971	..	2·96	..
Total nitrogen ..	0·332	0·32	0·209	0·45
C/N ..	12·03	..	14·1	..

Composition of the seed: The reducing sugar shows an increase in the viviparous fruit over that of the normal (Table V). In the cotyledons of the former, however, there is only slight increase but in the plumule and radicle at the same time there is a considerable increase. This shows the translocation of reducing sugars to the plumule and radicle. The non-reducing sugar in the cotyledons as well as in the plumule and radicle of the viviparous fruit, is at a lower concentration than that of the normal fruit. The percentage of starch too declines with viviparous germination, which shows that break-down of the higher carbohydrates takes place to give rise to reducing sugars at viviparous germination.

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* The values represent averages of 10 observations in each case.

Total nitrogen is practically constant in both the cotyledons and the plumule and radicle of the normal fruit and in contrast to this it decreases in the cotyledons and increases in the plumule and radicle of the viviparous fruit (Table V). Since nitrogen increases in the plumule and radicle, as it disappears from the cotyledons, it seems likely that the reserve nitrogenous compounds of the cotyledons are transferred to their point of utilization in the seedling in some form.

Summary

The discovery of viviparous germination in a local variety of *Mangifera indica* stimulated the present piece of investigation. Certain physiological and chemical changes in the mesocarp and seed of normal and viviparous fruits have been studied and the following are the conclusions reached.

The mesocarp of the viviparous fruit as compared to normal is characterised by lower output of CO_2, lower moisture percentage and lower pH on the one hand and a decreased amount of non-reducing sugars, a decreased amount of starch and of total nitrogen but an increased percentage of reducing sugars on the other. The mesocarp of the normal fruit shows higher CO_2 output, higher moisture content, higher pH, higher percentage of non-reducing sugars, of starch and of total nitrogen but lower percentage of reducing sugars.

The endocarp in the vivparous fruit is invariably split at its broader end. Germination experiments with regard to the rōle of endocarp in hastening germination reveal that its split condition favours germination. In the normal fruit the endocarp is intact which might offer some resistance to the extrusion of the radicle.

The changes detected inside the seed of the viviparous fruit in contrast to the conditions existing in the normal fruit are: (i) increase in the rate of respiration, more so in the plumule and radicle than in the cotyledons; (ii) increase of temperature; (iii) increase of moisture content; (iv) decrease of pH especially in the plumule and radicle; (v) loss in starch and in non-reducing sugars; (vi) increase in the quantity of reducing sugars, especially so in the plumule and radicle and (vii) loss of nitrogen from the cotyledons and increase in the plumule and radicle.

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Explanation of Plates

PLATE IX

Viviparous germination in mango (*var.* Deshi)

PLATE X

Stages of viviparous germination in mango (*var.* Deshi)

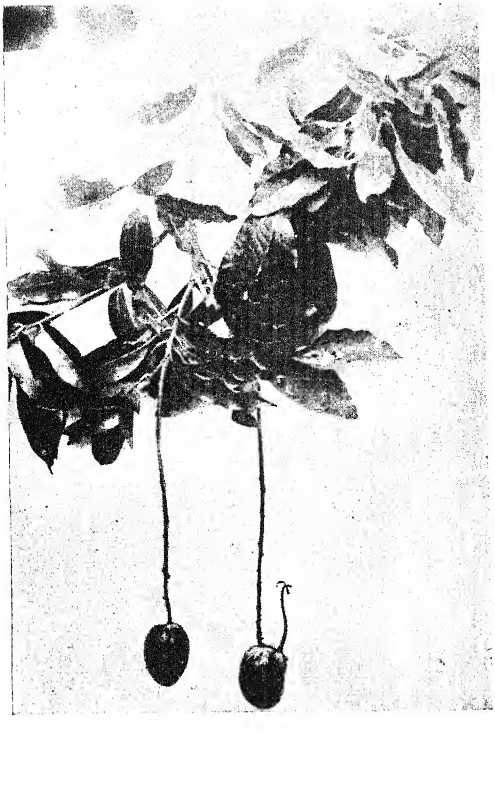
A. Cotyledous split open to show the enlargement of the plumule.

B. Protrusion of the radicle between the cotyledons.

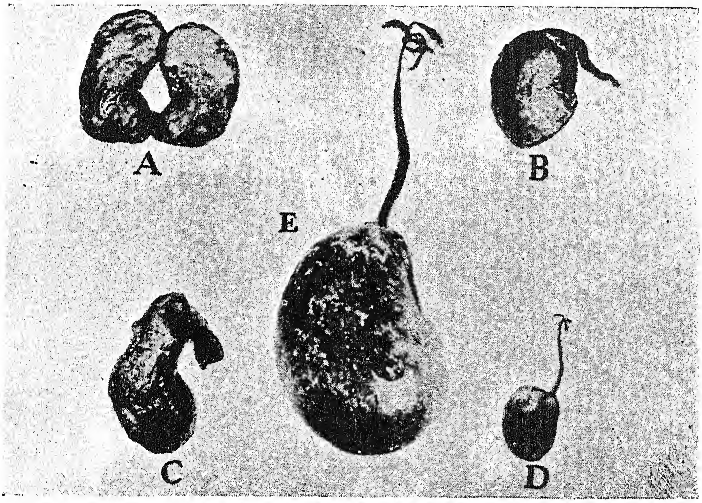
C. Arched condition of the epicotyle.

D. Young seedling with rudimentary leaves.

E. The same **(D)** enlarged.



B. N. SINGH AND B. N. LAL—*VIVIPAROUS GERMINATION IN MANGO*



B. N. SINGH AND B. N. LAL—*VIVIPAROUS GERMINATION IN MANGO*

INVESTIGATION ON F_1 AND F_2 HYBRIDS BETWEEN *BRASSICA CARINATA* AND *RAPHANUS SATIVUS*

BY

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Introduction

The cross between *Brassica carinata* (Abyssinian mustard) and *Raphanus sativus* (Radish) has been recorded by Karpechenko (1929), Morinaga (1933) and Nagaharu (1935). Morinaga mentions that a *Carinata-Raphanus* hybrid (F_1) produces no constant bivalents in micro-sporogenesis. He has, however, drawn a place at first metaphase showing 22 univalents and two bivalents. Nagaharu confirms the complete absence of pairing.

In the present investigation two hybrids belonging to F_1 and F_2 generations were raised in 1935 and 1936 respectively at Cambridge (England) and were cytologically examined. The meiotic chromosomes were studied exclusively on smear preparations fixed in La cour 2B followed by the Iodine-Gentian-Violet method of staining.

2. Meiosis in Parental Species.

(a) *B. carinata* ($2n=34$). This species was cytologically examined by a few who have recorded its chromosome number to be 34 and meiotic process regular. No multivalents were observed at prophase of meiosis. In the present investigation twelve nuclei were analysed at diakinesis, of which five showed two tetravalents (Fig. 1), six only one tretravalent in each and one no multivalent. At anaphase numerical segregation of chromosomes is regular. (Fig 2).

(b) *R. sativus* ($2n=18$). At diakinesis in this species nine bivalents are regularly observed. Maeda and Sasaki (1934), however, report the presence of multivalents in two horticultural varieties.

3. F_1 Hybrid

The hybrid grew quite vigorously with glabrous stem and red tinge at the nodes. The leaves were lobed and smooth. The petals were white and the stigma very much swollen. The proportion of dehiscent to non-dehiscent part in the fruit was approximately 2:1.

Meiosis.

It was examined chiefly from diakinesis onward. Four pollen mother cells were studied at mid-diakinesis, but exact analysis of all the chromosome configurations in any one of them was difficult. Roughly the number of bivalents varied between 6 and 9. After undergoing pro-metaphase the nucleus passes into metaphase when again a variable number of bivalents is seen. Owing to the stretched condition of bivalents along the spindle axis in side view and their larger size in polar view they are easily discriminated from the univalents (Figs. 3 and 4). Twenty-six plates were studied at this stage and the results are shown below:—

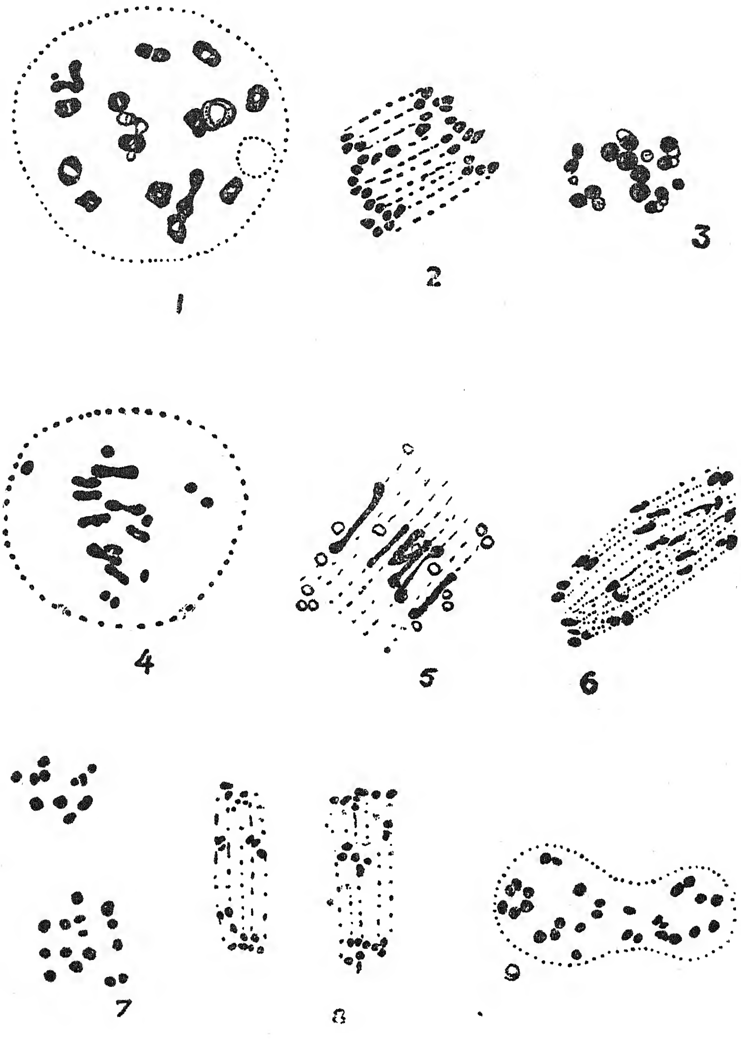
Bivalents	0	1	2	3	4	5	6	7	8	9	Total
P.M.Cs.	—	—	2	—	5	5	4	4	2	4	26

In a side view plate one heteromorphic bivalent was also observed (Fig. 5). Its absence from other plates may suggest that the chromosomes concerned might have remained unpaired. Secondary associations between bivalents and univalents are quite frequently observed. In all the three polar views with nine bivalents two groups of two secondarily associated univalents were constantly observed (Fig. 3).

At anaphase the bivalents disjoin quite regularly while the univalents show the following behaviour:—

(1) Either the univalents reach the equator along with the bivalents in which case two types of behaviour are observed: (a) The univalents travel to the opposite poles possibly at random, but sometimes they may split and the halves may travel to the opposite poles or the splitting may occur on their way to the poles in which case the chromatids possibly travel to the same pole. This occurs more or less simultaneously with the disjointing of the bivalents. (b) Several univalents are seen lagging on the equator which sometimes show their division. Such a condition may sometimes lead to the formation of a restitution nucleus (Fig. 6).

(2) Or the univalents do not reach the equator and may join the nearer constituents of the bivalents at the opposite poles. Occasionally they remain scattered between the poles forming a sort of bridge which may possibly result in a restitution nucleus (Fig. 9).



Figs. 1—9. Meiosis in *Brassica carinata* (2n=34),×3,200. 1. Diakinesis, two tetravalents and thirteen bivalents and a nucleolus. 2. I anaphase showing regular segregation of chromosomes. Meiosis in F_1. *B. carinata.* × *R. sativus.* × 3,290. 3. I metaphase polar view showing nine bivalents and eight univalents. Notice secondary associations among bivalents and univalents. 4. I metaphase side view showing nine bivalents and eight univalents. 5. I early anaphase with six bivalents (one of which is heteromorphic) and fourteen univalents. 6. I late anaphase, notice the splitting of lagging univalents. 7. II metaphase polar views where some univalents have divided at I division. 8. II division spindles, notice the lagging of univalents. (Meiosis in F_1. *B. carinata*×*R. sativus.* ×3,200,) 9. restitution nucleus with 29 chromosomes.

Transitional conditions may also be expected. At second division, the univalents of a restitution nucleus (Fig. 9) are seen arranged on the equatorial plate and undergoing regular division (Figs. 10 and 11). Occasionally lagging and losing of one or two univalents are also observed. Such a pollen mother cell results in a dyad, with 2n or nearly 2n number of chromosomes. If a restitution nucleus is not formed the two groups of chromosomes without undergoing interkinesis enter into the second division when again lagging is sometimes observed. (Fig. 8). This results in a tetrad. The hybrid produced dyads and tetrads roughly in equal numbers.

After a certain stage the anthers began to dry off and they were not observed to dehisce. 1—2% good pollen was observed by teasing out the anthers in aceto-carmine.

4. F_2 Hybrid

The F_1 hybrid was extremely sterile. It was growing along with several other Brassica hybrids, but produced no fruits even by open pollination. Since the anthers did not dehisce they were teased out in drops of tap-water on a slide and pollination was then effected by simply dipping the stigma into this water, which was always examined under the microscope to ensure that sufficient pollen was present. But the flowers were not bagged. By such a method two feebly developed pods were obtained (but this does not altogether exclude the possibility of an out-cross) which yielded only one small round seed (somewhat red) which gave the present F_2 hybrid.

It produced hairy and lobed leaves and a small greenish white bulb. In other characters it entirely resembled the F_1. In this hybrid the anthers, as a rule, ruptured quite normally.

The hybrid showed 28 chromosomes in the root-tip cells fixed in La cour 2B followed by the Iodine-Gentian-Violet method of staining.

Meiosis.

At very early diakinesis (or late diplotene) one nucleus and at late diakinesis also one nucleus were studied which showed the following configurations.

Early diakinesis: 1 tetravalent, 6 bivalents and 12 univalents. (Fig. 13).

Late diakinesis: 1 trivalent, 8 bivalents and 9 univalents.

At I metaphase seven polar views were examined when again variable pairing was observed as shown below. At this stage some bivalents can be distinctly marked but all of them cannot be definitely ascertained, hence the number of bivalents was always confirmed by subtracting the observed number from the somatic number 28. Trivalent which was observed only twice could be distinctly made out. Occasionally at this stage nucleolar fragments were also detected. Secondary associations were quite often observed.

P.M.Cs.	Trivalents.	Bivalents.	Univalents.
1	—	10	8
2	I	10	5
*3	—	10	8
4	—	6	16
5	—	8	12
6	—	10	8
7	I	5	15

* Drawn in Fig. 14.

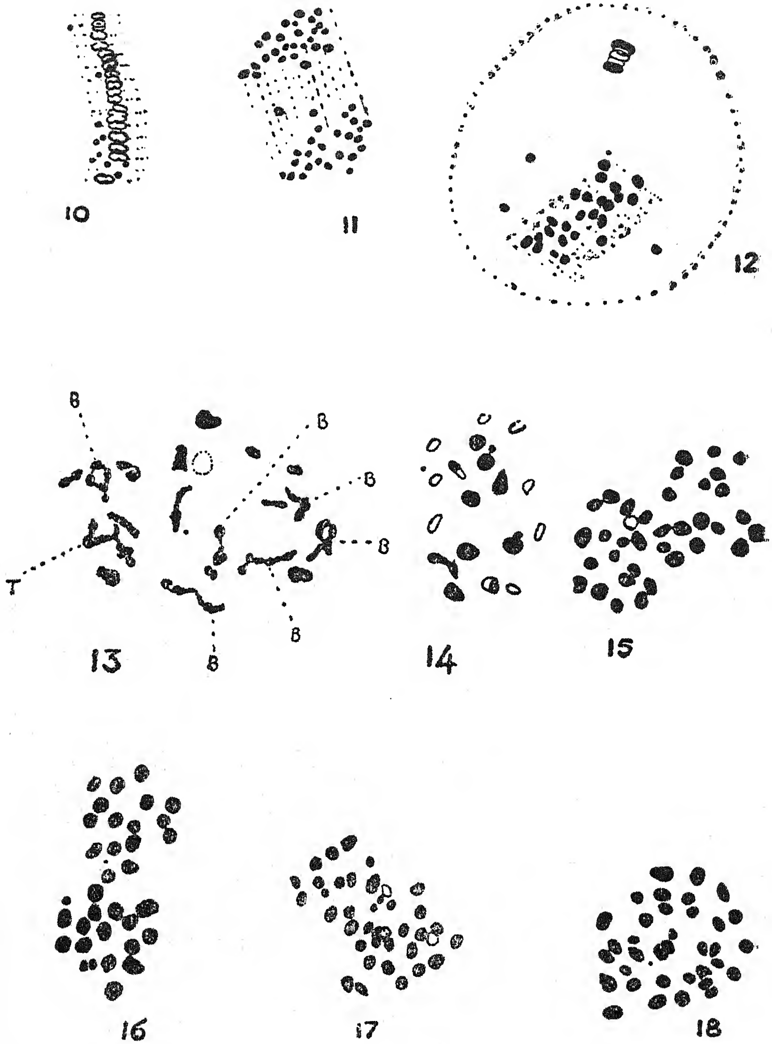
Very often plates showing more than 28 univalents are observed (Figs. 15-18). They possibly represent different types towards the formation of restitution nucleus when variable numbers of univalents have divided. Chromosomes were counted from nine such plates which gave the following distribution:

No. of univalents ..	34	35	36	37	38	39	40
Frequency of P.M.Cs. ..	1	2	3	1	—	—	2

At I anaphase the univalents behave in a similar manner as observed in F1 (see page 138). At interkinesis, when the univalents were seen scattered within the cavity and had not lost their boundary, chromosome number was determined from three such pollen mother cells in both the daughter nuclei as shown below. The division of univalents at this stage was quite often observed.

P.M.Cs.	I Pole	II Pole	Total
1	18	10	28
2	12	16	28
3	14	18	32

At II division some irregularities were quite often noticed, such as the lagging of several chromatids and the fusion of spindles.



Figs. 10—18. Side view of a restitution nucleus 11. late anaphase. 12. II division. (Meiosis in F2 *B. carinata.* ×*R. sativus.* ×3,200.) 13. Early diakinesis showing one tetravalent (T) six bivalents (B) and 12 univalents. (14) I metaphase with ten bivalents and 8 univalents and two nucleolar fragments. Various types towards the formation of restitution nucleus in F2 (2n=28) when variable numbers of univalents have divided. ×3,200. 15. With 36 chromosomes. 16. With 35 chromosomes and possibly a necleolar fragment. 17. With 40 chromosomes. 18. With 35 chromosomes.

The hybrid produced dyads, triads and tetrads in the following percentages, examined from one preparation only:

Dyads	Triads	Tetrads
18	6	76

The pollen was examined in acetocarmine and two types were distinguished: 1. Large pollen which took the red stain. 2. Small ones which did not stain and were yellow. Some variation among these two types was also noticed. Pollen counts were made on three different days as shown below.

	Date.	Large pollen		Short pollen	
		Actual No.	percentage.	Actual No.	Percentage.
1.	25-5-1936.	26	12%	189	88%
2.	28-5-1936.	17	7%	222	93%
3.	29-5-1936.	26	14%	159	86%

By open pollination only one seed was obtained from this hybrid.

Summary

The paper deals with the cytology of *Brassica carinata* (2n=34), *Raphanus sativus* (2n=18) and their F1 and F2 hybrids.

At diakinesis in *B. carinata* occasionally one or two tetravalents were observed. No such multivalents were formed in *R. sativus*.

In F1 at meiosis variable pairing, up to nine bivalents was seen. Heteromorphic bivalent was also observed once among twenty-six plates examined.

The F2 hybrid showed 28 chromosomes (2n). At meiosis a variable number of bivalents up to 10, with occasional multivalents (trivalent and tetravalent) was observed.

The hybrids in both the generations were extremely sterile.

In conclusion, I wish to express my hearty thanks to Prof. B. Sahni, F.R.S., for his kindness in making very valuable suggestions during the preparation of the manuscript; to Mr. A. E. Watkins, School of Agriculture, Cambridge, England, for giving me an F1 seedling of the cross. The F1 and F2 hybrids were grown at Cambridge where all cytological preparations and observations were also made, except a few details which were finished in this Institute. I am also thankful to Mr. J. C. McDougall, Director of Agriculture and Mr. K. P. Shrivastava, Second Economic Botanist, C.P., for giving me all facilities to work in the laboratory.

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ON THE DISCOVERY OF THE PROTHALLUS OF *LYCOPODIUM* IN INDIA

Preliminary note

BY

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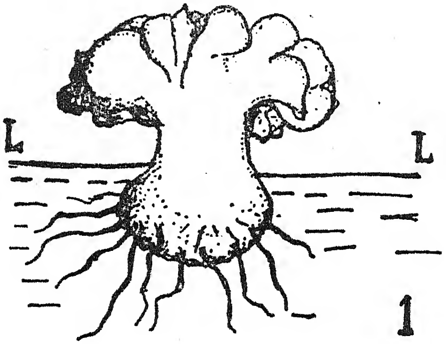
The genus *Lycopodium* has been the subject of repeated investigation by many workers. But the work in the past has been mainly concerned with the sporophyte generation. Our knowledge of the gametophyte is due chiefly to the work of Treub (1) on some tropical species from Java, to Bruchmann's work (2) on species from the north temperate zone in Europe, to the brilliant researches of the Rev. Dr. J. E. Holloway (3) and Miss Edgerley (4) on the New Zealand species and to the work of Spessard (5) and others on American species of the genus.

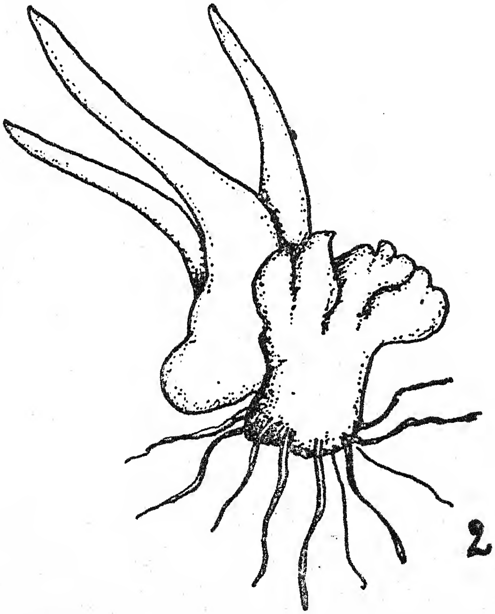
N. P. Chowdhury of Lucknow (6) (7) who has made a comprehensive study of the genus as represented in India, has described eight species from this country. But in none of them has the gametophyte yet been recorded in India.

In some parts of the forests in North Canara *Lycopodium cernuum* (L.) grows quite wild and an attempt at finding its prothallus was thought worth while. My efforts in this direction for the last three years resulted in the discovery of a few prothallia this year. The object of this preliminary note is to give a short account of these prothallia and the locality from where they have been gathered.

The prothallus is partially subterranean (Fig. 1) and was found on the cutting of a quarry on the eastward slope of a hill near Karanzol station on the Portuguese West Indian Railway. The hill is full of clay derived from the decomposition of granite; much of it is made up of kaolin. The soil is covered by a thin layer of dwarf mosses, Jungermanniales, Cyanophytic algae and fungi, all lumped together in a common mass. Small springs of water abound in the area. Scrambling amongst the bushes at the foot of the hill, a few plants of *Lycopodium cernuum* (L.) peep out here and there. The top of the hill is clad with rich angiospermic vegetation. At some places in shady parts in the middle of the jungle, *Lycopodium* reaches a height of three feet or more and is seen at its best. As we ascend the hill further, nothing else than *Lycopodium* and grass can be seen. Every plant of *Lycopodium* here is connected with its

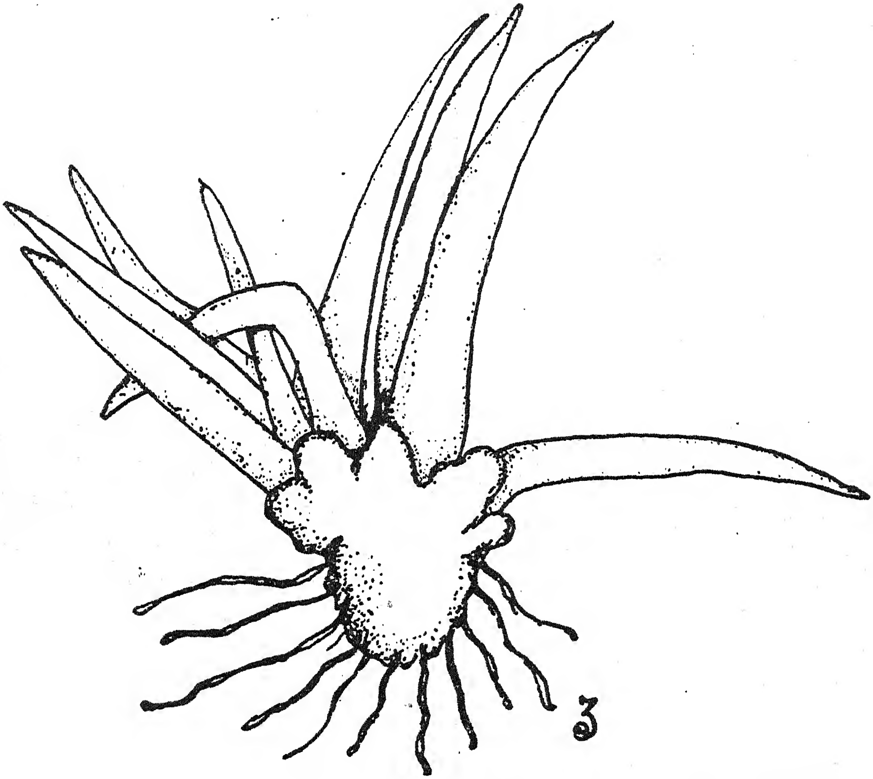


Text-fig. 1.—*Lycopodium cernuum.* Green prothallus with leafy lobes above soil level (L-L). × 28.



Text-fig. 2.—*Lycopodium cernuum.* Prothallus with leafy crown at the right, protocorm at the left bearing three protophylls. × 28.

neighbouring plant by horizontal vegetative shoots. No trace of the gametophyte could be seen here. A little more ahead to the west of this area there is a clean cut quarry and a deep *nalla* on the banks of which small green thalloid cushions of the gametophytes make their appearance (Fig. 1).

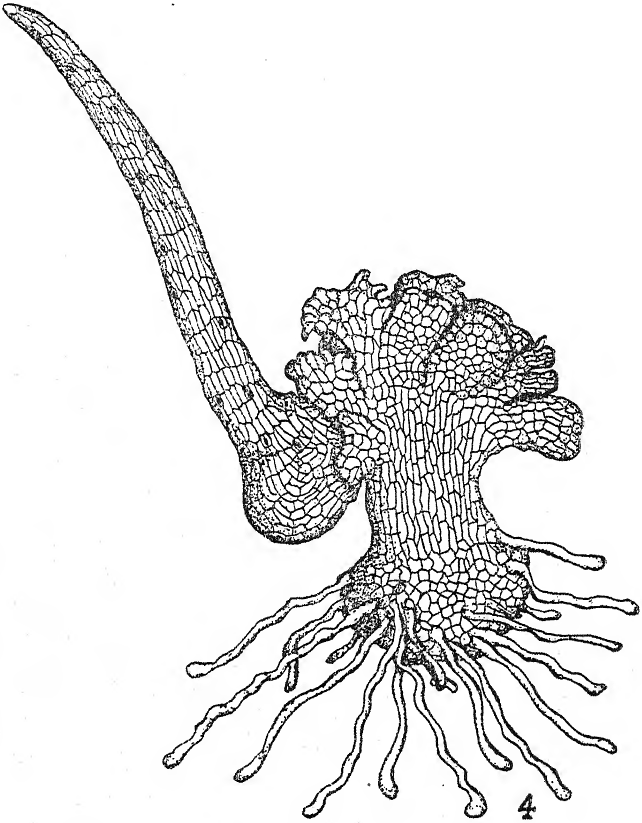


Text-fig. 3.—*Lycopodium cernuum*. Old prothallus with attached sporophyte bearing nine protophylls. × 28.

A careful survey reveals a few more juvenile plants with their characteristic protophylls. It was from this locality that the gametophyte described here were collected.

The prothallus is quite green and firmly adherent to the soil. It is solid and resembles a head of cauliflower in miniature. It generally measures 2 mm., varying from 0.5 mm. to 2.5 mm. The top of the prothallus is made up of thin green lobes which form a crown on the solid column below (Figs. 1, 2, 4). The crown of leafy lobes is fully exposed and lies over the surface of the soil engulfed by the cyanophytic felt and mossy turf (Fig. 8).

The base of the prothallus is broad and rounded. It shows a rich pubescence of rhizoids and mycorrhiza. Antheridia and in a few cases archegonia are discernible below the crown of lobes. In some specimens the young sporophytes are seen still attached to the gametophytes (Figs. 2–6, 8). In such cases the crown of leafy lobes may be shifted to one side of the prothallus and the simple structure of the protophylls and the protocorm comes prominently into view.



Text-fig. 4.—*Lycopodium cernuum*. Prothallus with leafy crown on the right, and a protocorm on the left bearing a single protophyll. Note the rhizoids. × 58.

A detailed study of these gametophytes and the young plants is in progress.

I take this opportunity to express my deep sense of gratitude to Dr. B. Sahni, F.R.S., for his valuable criticism and advice in connection with the present work and to Prof. D. L. Dixit, and Prof. V. V. Apte of Fergusson College, Poona for their kind help.

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Explanation of Plate XI

Prothallus of *Lycopodium cernuum.*

Fig. 5. Prothallus with a single protophyll placed on the shaft.

Fig. 6. Prothallus with three protophylls, and the crown of lobes shifted to one side.

Fig. 7. Two prothalli, one with a crown of lobes only (right), the other with a single protophyll (left).

Fig. 8. Four sporelings and a green lobed prothallus growing on the cyanophytic felt. × 5.

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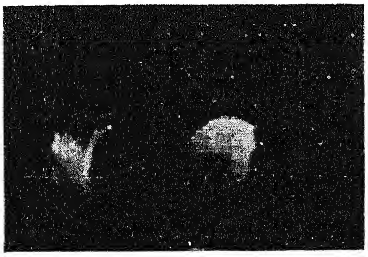

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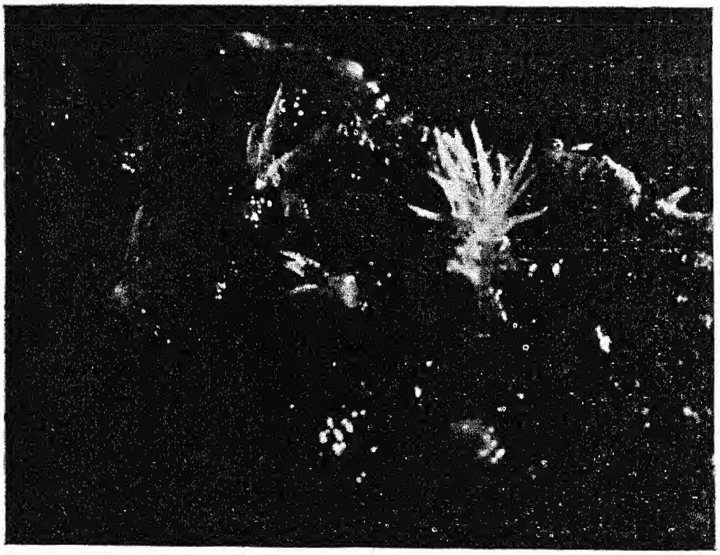

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T. S. MAHABALE—PROTHALLUS OF *LYCOPODIUM*

DEVELOPMENT OF OVULE AND EMBRYO-SAC OF *TAMARINDUS INDICA* Linn.

BY

Asoka Kumar Paul, M. Sc.

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Introduction

Tamarindus indica Linn. the common tamarind tree, which belongs to the family Leguminosae and sub-family Caesalpiniodeae, is found abundantly in the tropics. As very little is known about its life-history, it was thought desirable to make a study of the reproductive phases of the plant. The present paper deals with the development of the ovule and embryo-sac. An account of the microsporogenesis of the plant will be published in a separate paper.

A general review of the embryology of the Leguminosae has been given by Schnarf (15). Since then Roy (12), Datta (3), Singh and Shivapuri (18) and Samal (16) have reviewed the relevant literature on the subject.

Material and Methods

The material used in this investigation was obtained from several plants growing round about Calcutta. Buds of various sizes were fixed in a number of fixing fluids; the best results being obtained with Allen's modification of Bouin's fluid and Licent's fixative. For rapid penetration of the fixing fluid, the bracts, the calyx and the corolla were removed, and the buds were trimmed at both ends. An exhaust pump was used in all cases. Fixation was always done in the field on bright days between 9 A.M. and 3 P.M. The fixed material was washed, dehydrated and cleared in the usual way and embedded in paraffin. Sections were cut to a thickness of 8 to 15μ and stained with either Haidenhain's iron-alum haematoxylin or Newton's Iodine-Gentian-Violet.

Development of Ovule

The ovules of *Tamarindus indica* are generally five to ten in number and are borne alternately on the two margins of the carpel. The ovules at first grow straight towards the dorsal wall of the ovary later they curve downwards and assume an anatropous form.

Simultaneously with the differentiation of the archesporium two integuments make their appearance at the chalazal end of the ovule. Both of them differentiate almost about the same time or sometimes the inner integument has been observed to differentiate first, but the outer one ultimately outgrows the inner.

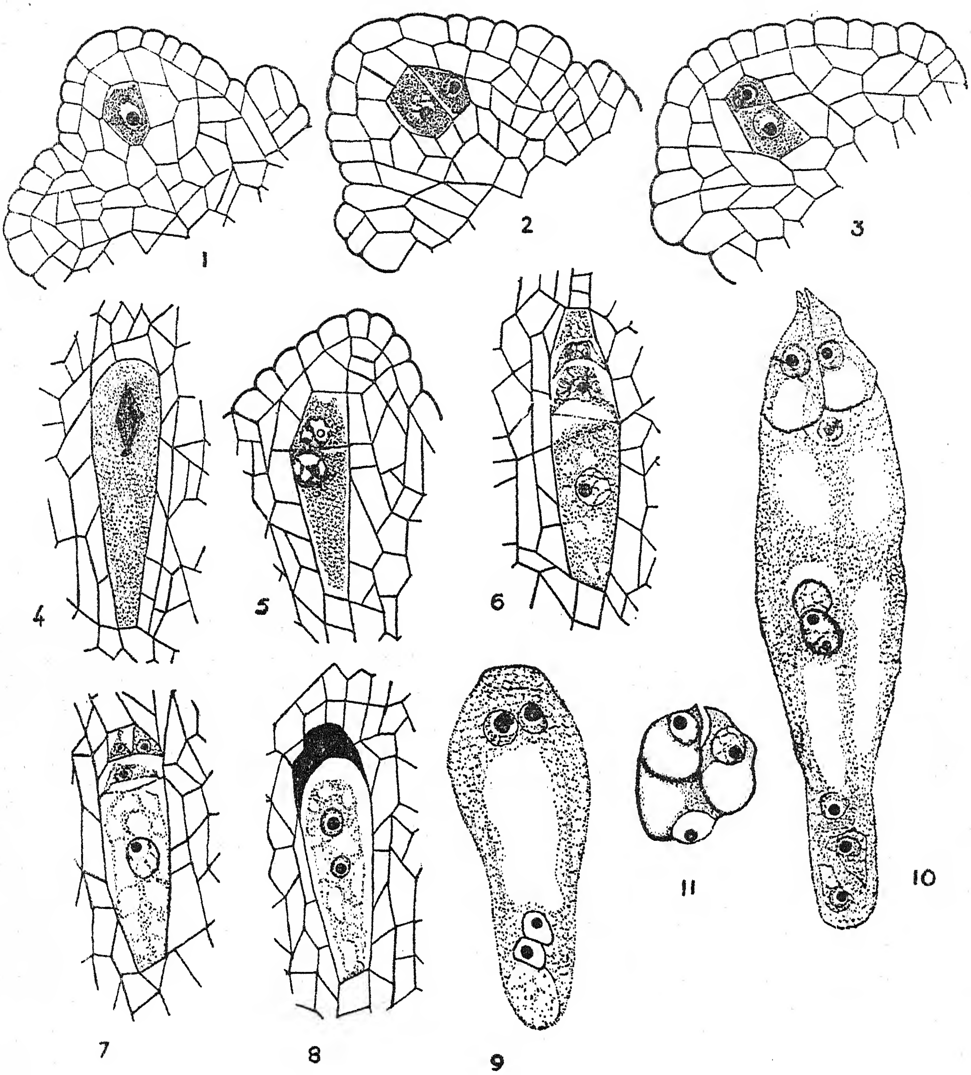
The inner integument consists of two layers of cells throughout its development. The outer integument varies in thickness, but usually consists of three to four layers of cells, except at the micropylar region, where it is thicker. As in other leguminous plants, both the integuments take part in the formation of the micropyle.

Development of Embryo-sac

The archesporial cell differentiates in the third layer of the nucellus (Fig. 1). It divides by a periclinal wall into a primary wall cell and a megaspore mother cell (Fig. 3). This primary wall cell again divides both anticlinally and periclinally forming a parietal tissue of many layers. Generally a single archesporial cell has been noted, but in some cases two or more have also been observed (Fig. 2).

The presence of more than one archesporial cell in the same ovule is not uncommon in the family Leguminosae. Martin (9) has recorded this in *Vicia and Trifolium*, Brown (1) in *Phaseolus*, Reeves (13) in *Medicago sativa* and Maheswari (8) in *Albizzia Lebbek*. Roy (12) also found a group of archesporial cells in *Pachyrhizus angulatus*, *Dolichos Lablab*, *Cajanus indicus* and *Lathyrus sativus*. Singh and Shivapuri (18) observed in *Neptunia oleracea* two archesporial cells giving rise to two megaspores mother cells lying side by side.

The division of the archesporial cell into a wall cell and the megaspore mother cell seems to be a characteristic feature of this family. Guignard (5) working on 40 species of leguminous plants came to the conclusion that in the family Leguminosae the archesporial cell in the first instance divides normally into the primary wall cell and the megaspore mother cell; the former on further division produces a wall tissue of varying thickness, the thickest being in Mimosoideae and Caesalpinioideae. Maheswari (8) found a thick wall tissue of 6 or 7 layers of cells in *Albizzia Lebbek*. The wall cells, however, were found to be altogether absent in *Lathyrus odoratus* by Jönsson (7) and in *Orobus angustifolius* by Guignard (4). Datta (3) found in *Cassia Tora* the archesporial cell to be buried in the 3rd or 4th layer of the nucellar tissue and there was no division of the archesporial cell into a wall cell and the megaspore mother cell. Saxton (17) found the same thing in *Cassia tomentosa*. Roy (12) on the other hand observed a distinct wall cell in *Lathyrus sativus*. In other cases studied by him no wall cells were seen to be cut off. It seems from the above data that the cutting off of the parietal cell may be of some specific value.



All figures were drawn with the aid of a camera lucida.

Text Figs. 1 to 11—Fig. 1. The differentiation of the archesporial cell in the third layer of the nucellus. × 650. Fig. 2. Two archesporial cells lying side by side. Note the origin of the primordia of the two integuments almost simultaneously. × 650. Fig. 3. The archesporial cell has divided into a primary wall cell and the megaspore mother cell. × 650. Fig. 4. The megaspore mother cell in the heterotypic metaphase. × 1,100. Fig. 5. Completion of the heterotypic division. A wall is laid down between the two daughter nuclei. Note the dissimilar dyad cells. × 1,100. Fig. 6. A linear tetrad of megaspores. × 950. Fig. 7. A T-shaped tetrad of megaspores. × 950. Fig. 8. Binucleate embryo-sac. The three degenerating megaspores are still seen, × 950. Fig. 9. Four-nucleate embryo-sac. × 950. Fig. 10. Mature embryo-sac showing the fusion of the polar nuclei in the middle of the embryo-sac. Note the position of the egg (Composite drawing from two sections.) × 650. Fig. 11. Mature synergids. Well formed vacuole is seen at the base of each. No 'filifom apparatus' is present. × 650.

The megaspore mother cell in *Tamarindus indica* gradually enlarges in size and undergoes the usual reduction division (Fig. 4). Presence of two megaspore mother cells at this stage has also been observed in a few instances. After the first division of the megaspore mother cell a wall is laid down between the daughter nuclei (Fig. 5). The lower cell of the dyad becomes elongated and is nearly three times as big as the upper cell. Roy (12) has also observed the same condition in all the species he has studied. Maheshwari (8) however found that in *Albizzia Lebbek* the lower cell of the dyad was only slightly larger than the upper cell.

The dyad stage is soon followed by the homotypic divisions. Both the cells usually divide at about the same time. The orientation of the homotypic spindle of the upper cell is slightly oblique to the long axis of the ovule.

A tetrad of four megaspores is formed, all separated from one another by distinct walls. Generally the arrangement of the megaspores is linear, but in some preparations T-shaped tetrads have also been observed (Figs. 6 and 7).

The upper three megaspores of the tetrad degenerate after some time. The degeneration in the three cells follows no definite sequence and any one of them may degenerate first, followed by the other two. The degenerating cells stain very deeply and have been traced up to the two-nucleate stage of the embryo-sac (Fig. 8).

Saxton (17) found in *Cassia tomentosa,* that the third megaspore from the micropylar end gives rise to the embryo-sac. Similar variations have also been noted by Guignard (5), who recorded that the megaspore mother cell produces an axial row of 2, 3 or 4 cells, of which the innermost or the one next to it divides to form an octonucleate embryo-sac. Miss Brown (1) records an abnormal case in which one of the daughter cells produced as a result of the heterotypic division, does not divide and an axial row of only 3 cells result, the innermost of which forms an octonucleate embryo-sac. Hérail's (6) work on *Medicago arborea* shows that the axial hypodermal cells of the nucellus divide by periclinal walls into two cells, the inner of which directly functions as an embryo-sac cell without undergoing tetrad formation. Young (19) reports another exception in *Melilotus albus* where the megaspore mother cell acts as a megaspore. Coe and Martin (2) who worked on the same plant state that the development of the embryo-sac proceeds in the ordinary way and the megaspore mother cell does divide. In *Acacia Baileyana,* Newman (10) found that three or four megaspores are formed and either the distal or the chalazal may function. He has also recorded the simultaneous development of two megaspores of the same tetrad.

The functioning megaspore begins to enlarge in size and its nucleus divides. At first the two nuclei remain close together, but afterwards they move to the opposite poles of the embryo-sac. The migration of the two nuclei to the opposite poles is effected by the gradual formation of a conspicuous vacuole in the embryo-sac. These two nuclei divide twice and an 8-nucleate embryo-sac with four nuclei at each pole is formed. Along with the development of the embryo-sac the surrounding cells become crushed and degenerated. The mature embryo-sac is broader at the micropylar end and narrow at the chalazal end. The egg-aparatus is normal. The egg is placed at first between the two synergids, but later it protrudes a little below them. A conspicuous vacuole is always found in the egg above the nucleus in the mature stage (Fig. 11). The presence of a filiform apparatus in the synergids could not be detected even with differential staining. The polar nuclei fuse completely at or near the middle of the sac before fertilisation. The antipodals are definite cells and are seen to exist even after the fusion of the polar nuclei. They are present in opened flowers. Datta (3) also observed antipodal cells in *Cassia Tora* till fertilisation. Guignard (5) who examined a large number of species concluded that the antipodals persist till fertilisation in Mimosoideae and Caesalpinioideae, but they last for a short time in Papilionatae. Brown (1) working on *Phaseolus vulgaris*, Reed (14) on *Arachis hypogea* and Reeves (13) on *Medicago sativa* support the general statement of Guignard, but Singh and Shivapuri (18) observed the antipodal cells to be ephemeral in *Neptunia oleracea.*

Summary

1. The development of the ovule and embryo-sac in *Tamarindus indica* Linn. has been worked out.

2. The ovule possesses two integuments which originate almost simultaneously. Both of them take part in the formation of the micropyle.

3. The archesporial cell differentiates in the third layer of the nucellus. More than one archesporial cells are sometimes present and develop up to the megaspore mother cell stage.

4. A wall cell is cut off. The megaspore mother cell gives rise to a linear or T-shaped tetrad of megaspores, of which the chalazal is functional.

5. The development of the embryo-sac corresponds to the normal type. The fusion of polar nuclei takes place before fertilisation. The antipodal cells persist till anthesis. The synergids do not show any filiform apparatus.

In conclusion, I take this opportunity of expressing my heartfelt thanks to Mr. I. Banerji, under whose direction the work was carried out in the Botanical Laboratory of Calcutta University in the year 1933.

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STERILITY IN *COLOCASIA ANTIQUORUM* SCHOTT.

BY

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Colocasia antiquorum is a common aroid which grows abundantly in marshy places during the rains in Bengal. The petiole and rhizomes are generally eaten by the poor people. The plant propagates itself vegetatively and seed formation has not been noted under natural conditions in Bengal.

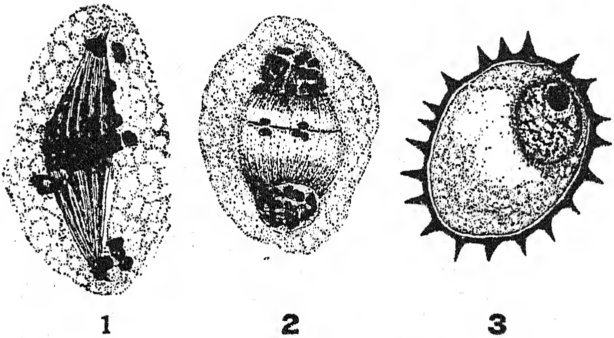
As at the outset of the investigation it was thought that non-formation of seeds may be due to non-development of viable pollen or female gametophyte, or to the abortion of ovules or embryo; a study of microsporogenesis and development of the female gametophyte was therefore undertaken. Maeda (2) has given an account of the microsporogenesis of the plant. He observed certain irregularities in the chromosome behaviour of the plant during meiosis and suggested that this might be the cause of sterility. He also determined the haploid chromosome number of the plant, which is fourteen. In 1934 the present writer briefly reported elsewhere (1) that non-formation of seeds in *Colocasia antiquorum* is due to the non-development of the female gametophyte. The present paper not only confirms Maeda's observations but gives a detailed account of the degeneration of the female gametophyte in *C. antiquorum* which is the cause of sterility.

Material and Methods

The material was collected from plants growing in the locality and fixed between 12 noon and 4 P.M.; Allen's modified Bouin's fluid was used for fixation and an exhaust pump was always used to ensure rapid penetration of the fixing fluid. The material was kept in the fixing fluid for 24 hours, and then run up to 70 per cent. alcohol in the course of an hour, the green colour removed by using lithium carbonate, dehydrated and cleared in the usual way. Sections were cut 8 to 14 microns thick depending on the stage required for study. Heidenhain's iron alum haematoxylin was used for staining. Some preparations were counterstained with Orange G.

Observation

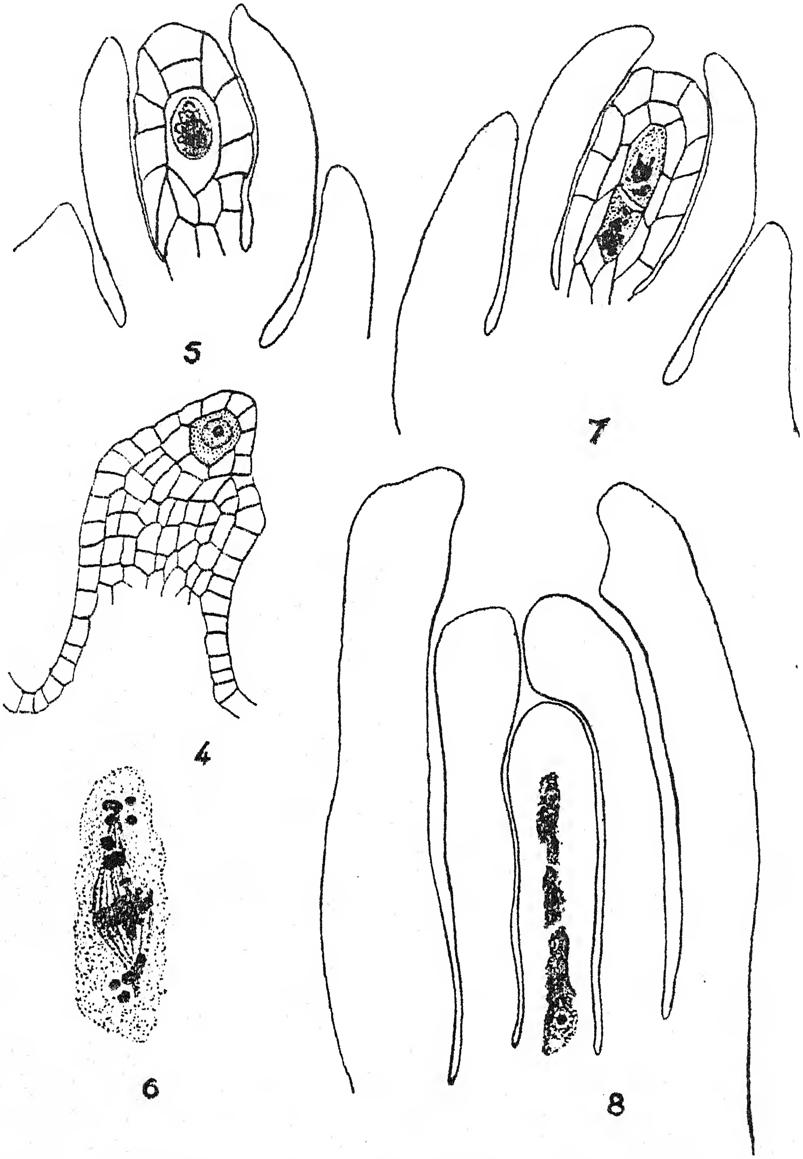
During microsporogenesis no abnormal behaviour of the pollen mother cells is noted up to the metaphase of division I. With the anaphasic separation of the chromosomes irregularities in the meiotic division are first noted. While most of the chromosomes are oriented on the equatorial plate, a few univalents and bivalents move to the poles. A few of them even pass out into the cytoplasm. The appearance presented at this stage is represented in Figure 1. Non-disjunction of the chromosomes has also been observed in certain cases and as a result the daughter nuclei do not always contain the equal chromosome complement. The cast out chromosomes form diminutive spindles in the cytoplasm. Figure 2 represents a telophase stage in which a few choromosomes not included in the nuclei may be seen. The daughter nuclei are separated by a cell wall. The homeotypic division which very soon follows shows no marked irregularity. Cell walls are laid down after the completion of the division and divide the protoplast into four parts and thus a tetrad of microspores is produced. Depending on the orientation of the homotypic spindles the pollen tetrads are either tetrahedral or isobilateral in arrangement. The nuclei of each of the microspores increase in size and they ultimately get separated from each other. At this stage they are more or less triangular in shape but they very soon round off. No case of polycary or any micronuclei has been observed. The young microspores appear to be of the same size. Pollen grains when fully formed, however, show great variation in size; some pollen grains appear to be double in size of the others, intermediate forms being also present.



Text Figs. 1—3; Explanation in text. × 2,800.

In the early stages of the development of the pollen grains the tapetal tissue which is uninucleate seem to be projecting inwards into the anther cavity. At this time the pollen mother cells have rounded off and have more or less a polygonal outline. During synezesis of the pollen mother cells the cell walls bounding the tapetal cells appear to become indistinct and a number of nuclei are noted in the cytoplasm which appears to be somewhat homogeneous. Later on the tapetal cells progress inwards very considerably and in some cases are seen to form bridges across the anther cavity. The nuclei appear to have increased slightly in size and the plasmodium shows vacuolisation at places. The plasmodium next fills the anther loculus and the nuclei are seen to be scattered irregularly. At this stage the young microspores are uninucleate and spines are noted on the exine (Fig. 3). The tapetal nuclei have very varied form at this stage, mostly they are elongated and round, but other forms have also been noted. These varied forms arise on account of the division of the nuclei amitotically. It might be mentioned that up to this stage division of the tapetal nuclei had not been observed. During amitotic division the nucleus seems to be drawn out at both ends and presents an hour glass like appearance. The middle portion gradually becomes attenuated and then constricts and thus the daughter nuclei are separated. Both the nuclei have tail like projections at first, but these are soon drawn in and the nuclei become elongated or round in form.

During megasporogenesis the ovule initials appear in large numbers from the placental tissue and at first consists of a group of homogeneous cells. The primordium of the integuments appear early and before the differentiation of the megaspore mother cell. A single hypodermal archesporial cell is differentiated and this functions as the megaspore mother cell. (Text Fig. 4). At a slightly later stage both the inner and the outer integuments are well differentiated. Their relative position is shown in Text Figure 5. After the megaspore mother cell has become differentiated the epidermal cell capping it divides periclinally. All the stages of division have been observed. The early prophasic changes in the megaspore mother cell appear to be quite normal. A spireme is formed and the nucleus passes into the synizetic stage sometimes enclosing the nucleolus in its meshes. The position of the nucleus is not fixed, sometimes it lies at the upper end of the protoplast; at other times it has been observed to lie at the lower end. During the heterotypic division a well formed spindle is noted but the chromosomes are irregularly clumped in the centre and their distribution to the poles is not regular. This stage is characterised by the same irregularities as has been noted during the reduction division of the pollen mother cells. Univalents and bi-valents appear to lie scattered in the cytoplasm and in the spindle, while most of the chromosomes are oriented on the equatorial region of the spindle. Text Figure 6 represents such a stage. At this time the inner integument has nearly reached the top of the nucellus while the outer integument stands at a little lower level. Degeneration of some of the megaspore mother cells is noted at this stage. On the completion of the heterotypic division two daughter nuclei are formed which are separated by a distinct wall. It is interesting to note that at about this time the epidermal cells of the stigma start growing and soon differentiate out as stigmatic hairs. These hairs are unicellular and uninucleate. The nucleus is more or less elongated and lies in the



Text Figs. 4—8; Fig. 4. Differentiation of the archesporial cell ×450. Fig. 5 megaspore mother all differentiated; Note position of outer and inner intiguments. × 450. Fig. 6. Hiterotypic division showing irregularly distributed chromosomes. × 930. Fig. 7. Degeneration of cells of dyad. × 450. Fig. 8. Disintegrated linear tetrad. Note position of integuments. × 450.

centre of the cell. Degeneration of the nuclei of the dyad is also commonly noted (Text Fig. 7). Those which do not degenerate undergo the homotypic division.

Irregularities in the movement of the chromosomes during this division are rarely observed. The homotypic spindles are quite normal and arranged perpendicularly with reference to the longitudinal axis of the ovule. In a few cases small supernumerary spindles are noted in the cytoplasm. These have obviously been derived from the castout chromosomes of the heterotypic division. As a result of the homotypic division a linear tetrad of macrospores are formed. Degeneration of all the four macrospores is commonly observed at this stage (Text Fig. 8). The degenerated tetrads appear as dark shapeless masses and occur in disjointed streaks in the centre of the nucellus. This ståge is very commonly met with. Out of hundreds of sections examined only in two instances was a binucleate and four nucleate embryo-sac found. Generally the centre of the nucellus contains dark streaks (disintegrated linear tetrads) and is devoid of any gametophytic tissue. Sections of fully opened flowers and flowers still older invariably show crumpling of the ovules and the absence of the female gametophyte in the nucellus, which is composed of a few layers of cells and is bounded by the integuments. In the mature ovule the outer integument stands at a higher level than the nucellus, the position of the inner integument is below the outer. Both the integuments are generally composed of two layers of cells.

Discussion

It is generally believed that plants which propagate vegetatively are sterile. Sterility in these plants is generally expressed by abortive pollen grains or ovules. The pollen grains do not attain their full size, appear to be shrivelled and often loose their protoplasmic contents. The formation of such non-viable pollen grains is often the result of irregularities in reduction division. Meada (2) who studied the formation of pollen grains in *Colocasia antiquorum* found lagging chromosomes during reduction division and very often pollen grains with many nuclei (polycary). During the course of the present investigation non-disjunction and irregular distribution of the chromosomes during the heterotypic divisions of both the micro and megaspore mother cells were observed in almost all preparations showing these stages. In certain preparations showing metaphase of division I, dimunitive spindles and also micro-nuclei lying outside the cytoplasm were noted. The homotypic divisions showed very little irregularity and the divisions appeared to be normal, except for the unequal number of chromosomes in the grand daughter nuclei. The pollen grains appeared to be normal but dimorphism in size was quite evident. No case of polycary or polspory was noted in any preparation.

Abnormalities during reduction division such as has been noted in this material has frequently been reported in hybrids. Such irregularities in meiosis are obviously due to germinal differences in the chromosomes. But again the mere fact of the chromosomes being distributed in varying and irregular numbers during reduction division is no positive proof that the plant is a hybrid; it might as well be due to malnutrition or abnormal environmental conditions. Sterility due to abortive ovules has also been noted in many horticultural plants. In *Colocasia antiquorum* sterility is due to the degeneration of all the megaspores and the subsequent abortion of the ovules which remain as crumpled masses.

Summary

An investigation on the non-formation of seeds in *Colocasia antiquorum* was undertaken. The results show that it is due to the non-development of the female gametophyte. All the four megaspores degenerate and the ovules subsequently abort. Irregular chromosome distribution during the reduction division appears to be a characteristic feature. Dimorphic pollen grains and a tapetal plasmodium has been noted. The nuclei of the plasmodium divide amitotically.

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ON SOME PROBLEMS OF CYTOTAXONOMY AND CYTOECOLOGY

BY

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A few years ago I attempted to correlate our knowledge of cytology with taxonomy (TISCHLER 1928, 1929). To-day the value of chromosome morphology and chromosome number is universally recognised as an important factor in systematic Botany. From a cytological point of view, plant genera may be classified into the following groups:

1. Those in which all the species have the same chromosome number (*Pinus*-type),
2. Those in which the species have multiple or polyploid chromosome numbers (*Chrysanthemum*-type),
3. Those in which the numbers are different but not polyploid (i.e., dysploid) (*Carex*-type),
4. Those in which the number of chromosomes shows only small variations of 1 or 2 (*Antirrhinum*-type).

All the four types mentioned above may occur in different sections of the same genus.

Why so many species of a genus are so stable that the chromosome number has never undergone any change in them is unknown. As regards the other types, we have in the last decade received interesting experimental material, which provides some explanation of the way in which new species may have arisen from the older ones.

MUNTZING (1930) showed for the first time, how an old Linnean species can be experimentally synthesised from two other good Linnean species, when he crossed *Galeopsis pubescens* ($n=8$) with *Galeopsis speciosa* ($n=8$) and obtained an "artificial" *G. tetrahit* ($n=16$). This tetraploid was quite different from the parents, but indistinguishable from a true *G. tetrahit* and fully fertile. Similarly, Heribert Nilsson (1931), another Swedish geneticist, crossed *Salix viminalis* (n=19) with *S. caprea* (n=19) and obtained a female tetraploid plant in the F_2 which was indistinguishable from *S. cinerea* (n=38). The new species arose by the combination of two diploid genomes, and we have in both cases an addition of chromosome sets comparable to the well known conditions in *Primula kewensis, Nicotiana digluta, Raphanus Brassica, Aegilotricum,* etc. The above facts represent a clear verification of Winge's theory about the origin of polyploid types in nature and we may now say with confidence that a new species can arise by hybridisation—as the late Dr. Lotsy (1925) claimed—and be perfectly stable. Nor is it necessary, that the species that are intercrossed, must have the same chromosome number. U (1935) crossed *Brassica compestris* (n=10) with *B. oleracea* (n=9) and obtained *B. napus* (n=19) with a new basic number in this genus.

With regard to the interesting question of the origin of new species in nature, we have here a problem that deals not only with taxonomical but also with ecological questions.In many cases it has been found that the polyploid (or dysploid, as in the *Cyperaceae*) species are better adapted to northern or alpine climates than the diploid ones. Hagerup (1928) demonstrated this for the *Ericaceae,* Miss Manton (1934) for *Biscutella laevigata,* Anderson and Sax (1936) for the north American species of *Tradescantia* and Sakai (1934, 1935) for some Japanese plants. I tried (Tischler, 1935), for the first time, to consider in this respect the angiosperm flora of a whole province. Unfortunately we do not know at present the chromosome number and degree of polyploidy in *all* the plants of any part of the world, but in many provinces of central Europe the percentage of such plants where the chromosome number is known far exceeds the unknown. From the flora of Schleswig-Holstein, which is the most northern province of Germany, we know the chromosome numbers of about 73% of the plants. About 45% of these are polyploids (including some dysploid ones like *Carex*), the monocotyledons outnumbering the dicotyledons in polyploidy in the ratio of 3 : 2. Approximately the same percentage occurs in East Prussia (the most north-eastern province of Germany), in spite of the fact that the flora of the two areas is appreciably different from one another.

It is a pity that the flora of countries situated further northwards (such as Iceland) or southwards (such as Sicily) is not yet sufficiently well investigated from this point of view. If we take into consideration the data, that we already possess, we find that the percentage of polyploids in Iceland is about 55, but in Sicily about 30. It seems reasonable to conclude that the influence of the glacial periods has enhanced the number of polyploids and decreased that of diploids, for the latter could not survive in the competition. We have at present only two exceptions: *Vaccinium* *uliginosum* (HAGERUP 1933) and *Campanula rotundifolia* BÖCHER (1936). both of which have diploid forms in Greenland and tetraploid in the south. A comparison of the two shows, however, that the diploid is much weaker and will hardly be able to survive in competition with the other plants growing in the north.

Recently I gave a cytological analysis of the flora of a small group of islands, the so-called "Halligen", situated in the North Sea (TISCHLER, 1937). They are annually overflowed by the sea during heavy storms and the plants living there must therefore be adapted to the salinity of the water. It was, however, surprising to note the difference in the behaviour of the halophytes proper, the grasses of the meadows and the weeds introduced by man. The percentage of polyploids in the first two groups is about the same as in the province of Schleswig-Holstein (i.e., 50%). Among the weeds, however, there are two categories: those, which have become completely naturalised to the new conditions are 100% polyploids, while others, which have not really become incorporated in the new flora but frequently come and disappear, are polyploids only to an extent of about 30%.

ROHWEDER (1934) got some very interesting results from his work on *Dianthus* carried out some time ago in this laboratory. The diploid species of this genus have poor adaptability and cannot stand lime and nitrogen; the tetraploid, on the other hand, are much more resistant and the hexaploid still more so. In a more recent paper (1936) he reports that the weeds of limestone grounds are mostly polyploids.

A change in chromosome number can thus give rise to new ecotypes and it seems that WULFF (unpubl.), working in this laboratory, has found such an example in *Jasione montana.* The haploid number of chromosomes in this species is 6, but plants growing on the dunes were found to possess 7 chromosomes. It has, however, not yet been demonstrated in this case, whether this difference is always constant.

Associated with polyploidy is also the question of a retarded rate of growth brought about by a slowing down of the rate of cell division. We know that in many cases a perennial form has originated from an annual in this way (to cite a well-known instance, diploid *Zea mays* is annual while the tetraploid form is perennial, RANDOLPH 1932). MUNTZING (1936) who has made a special study of this question, finds that in general the perennial species of a genus have higher chromosome numbers than the annual species of the same genus, and FAGERLIND (cited by MUNTZING 1936) has reported that even cases of seasonal dimorphism are sometimes correlated with polyploidy. Thus, the summer form of *Galium palustre* is diploid while the autumn form is octoploid.

There seems to be no doubt, therefore, that polyploidy is in most cases a decidedly advantageous acquisition which gives an organism some increased adaptability to conquer unfavourable conditions. It may of course bring about some other changes also. Thus, HAGERUP (1927) found that the diploid *Empetrum nigrum* found in Denmark is unisexual, while its tetraploid form found in the Arctic is bisexual, and BRUUN found (1932) that diploid *Primulas* show a pronounced heterostyly while the tetraploid forms belonging to the group "*farinosa*" have lost it and become homostylous. HEITZ (1927) has shown that in *Antirrhinum* and *Linaria* the addition of a single chromosome brings about a marked change in the size of leaves and fruits.

There are, however, great gaps in our knowledge to permit any far-reaching generalisations at present. Most of the plants investigated from this point of view belong to north and central Europe, Japan and North America. We know too little in this respect of the tropical and subtropical plants. There is a great field for such work in India and Dr. P. MAHESHWARI of Agra, with whom I had the pleasure of discussing modern karyological problems during his stay in my laboratory, requested me to direct the attention of Indian botanists to these questions. We have at present absolutely no records of chromosome numbers in the following families: *Olacaceae, Myristicaceae, Hernandiaceae, Moringaceae, Connaraceae, Zygophyllaceae, Burseraceae, Hippocrateaceae, Salvadoraceae, Icacinaceae, Actinidiaceae, Dipterocarpaceae, Frankeniaceae, Cochlospermaceae, Flacourtiaceae, Ancistrocladaceae, Sonneratiaceae, Lecythidaceae, Rhizophoraceae, Combretaceae, Sapotaceae, Symplocaceae, Loganiaceae, Pandanaceae, Flagellariaceae, Xyridaceae, Philydraceae, Stemonaceae, Taccaceae.* Informations on some others like *Casuarinaceae, Chloranthaceae, Santalaceae, Loranthaceae, Lardizalaceae, Menispermaceae, Meliaceae, Polygalaceae, Anacardiaceae, Sapindaceae, Rhamnaceae, Bombacaceae, Sterculiaceae, Dilleniaceae, Guttiferae, Melastomaceae, Myrsinaceae, Apocynaceae, Verbenaceae, Gesneraceae, Acanthaceae, Triuridaceae, Zingiberaceae, Palmae* and *Orchidaceae* are so meagre that further work would be most welcome.

To take a special instance, BHADURI (1933) has reported that diploid, tetraploid and hexaploid races of *Solanum nigrum* exist in India, while in Europe and North America we have only hexaploids. This indicates that it would be of great interest to know the chromosome numbers of our cosmopolitan weeds and compare the behaviour of the same species under different climatic conditions. It is possible that in India itself the same species has races with higher chromosome numbers in the Himalayas (influence of cold) or in the deserts (influence of heat and dryness; compare HAGERUP, 1932, who found an excess of polyploids in the hot and dry climate of Timbuktu) than in the more equable climate of some parts of the Deccan. We know that under experimental conditions variations of temperature have often brought about an abortion of the cell membranes in meiosis and a restitution nucleus formed thereby gives rise to diploid gametes and afterwards a tetraploid offspring. There is no doubt that the evolution of species is chiefly dependent upon qualitative alterations of chromosomes. It will be interesting to know how far these alterations in turn depend on changes in environment.

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ON THE VARIABILITY OF THE FLORAL PARTS OF *RONDELETIA ODORATA* JACQ.

(*R. speciosa* Lodd.), N. O. Rubiaceae (I)

BY

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The study of the variation and correlation in the flowers of *Rondeletia odorata* Jacq. was started from the month of August, 1936, when a few specimens of the same, together with other plants of the same family, were brought to the botanical laboratories of the Institute from the Victoria Gardens, Bombay, for the purposes of teaching. Similar observations on variation and correlation have been carried out by Mann (7) in his studies on the flowers of *Jasminum malabaricum* Wight.

Six hundred and ninety three flowers of the above specimen were examined with special attention to their calyx teeth, corolla lobes, stamens and pistils with the following results.

The number of carpels is constant in all the specimens examined. The number of stamens vary from five to seven, but it showed a distinct relation to the number of corolla lobes, i.e. a five-lobed corolla had five stamens, a six-lobed one had six stamens and so on; but the number of stamens showed very little correlation with the calyx teeth—the number of stamens being always less than the number of calyx teeth. In the present case, 31 per cent. of the total number (693) of flowers examined, showed correlation between the number of stamens and the calyx teeth, 62 flowers with 7 calyx teeth had 7 stamens each, and 151 flowers with 6 calyx teeth had 6 stamens each. My records show no relationship between the position on the branch and the number of teeth in the calyx and also the number of corolla lobes (3,5). The calyx teeth vary from 5 to 9, and Table I gives the number of calyx teeth in the flowers examined.

TABLE I

Number of calyx teeth

Number of flowers.	Number of calyx teeth.	Percentage.
6	5	0.87
199	6	28.71
366	7	52.81
118	8	17.02
4	9	0.58

The corolla lobes also vary from 5 to 7 and this variation is shown in Table II.

TABLE II

Number of corolla lobes

Number of flowers.	Number of corolla lobes.	Percentage.
100	5	14.43
493	6	71.14
100	7	14.43

From the above tables it is evident that the most frequent number of calyx teeth is 7, while those with 5 and 9 are very rare. The most frequent number of corolla lobes is 6.

The coefficient of variation of the calyx teeth is 10.29 per cent. and that of the corolla lobes is 8.95 per cent.

Correlation of the number of corolla lobes and the calyx teeth in the same flower

The study of such a large number of flowers clearly gives us an idea about the correlation of these two characters, viz. the number of corolla lobes and the calyx teeth. In 693 cases the corolla lobes and the calyx teeth were counted in the same flowers, and the results are shown in the table III, which shows the number of flowers with any particular number of calyx teeth say 5, 6, 7, etc. in relation with the various number of corolla lobes.

TABLE III

Number of calyx teeth	Number of corolla lobes			Total
	VII	VI	V	
IX	2	2	—	4
VIII	36	71	11	118
VII	62	269	35	366
VI	—	151	48	199
V	—	—	6	6
Total number of flowers examined	100	493	100	693

The correlation between corolla lobes and the calyx teeth is 0.4393+0.003 i.e. it varies between 0.4692 and 0.4092. This shows that though there exists some correlation between the two, they are but slightly correlated.

The deviation of the flower from its typical character may be arranged under the following heads (4):—

1. Irregularity of forms in members of one or more of the whorls.
2. Multiplication of parts.
3. Suppression or abortion of a whorl or part of a whorl.
4. Displacement or interference with the regular alternation of the whorl.
5. Coalescence of the parts or members of a whorl with one another.
6. Coalescence of the members of one whorl with those of another.
7. Substitution of spiral for whorled phyllotaxis.
8. Metamorphosis of the parts of the flower.

As for our present work the deviation of the flower of *Rondeletia odorata* Jacq. from the typical character come under the second head, viz. addition or multiplication of parts, which may be either due to *augmentation* or *chorisis, deduplication* or *unlining.* The collateral chorisis may be considered over here as a means of multiplication of the parts of a flower by division or splitting of a member in the course of its development, so that two or more members are produced in place of one. Jaeger (6) as early as 1814 observed in *Datura fastuosa* L., the occurrence of anther with a forked apex, besides the four normal ones. His observation is of value in so far as it points to a possible explanation of the sporadic occurrence of an extra sixth stamen also in *Datura Metel* L., which may very likely be due to a complete chorisis of one of the stamens. Jaeger's (6) case perhaps represents the first stage in chorisis. The increased number of calyx and corolla may also be explained similarly.

Increase in the number of parts in the calyx, corolla and androecium is known (2) in *Datura stramonium* L., also, but in every such case it is curious that the gynaecia are either tri or tetra carpellary. However, this is not the case in *Rondeletia odorata* Jacq., in which flowers are quite normal, so far as the gynaecia (bi-carpellary) are concerned. Similar observations were recorded by Wydler (9) and Vuillemin Paul (8) in *Phlox Drummondii* Hook and *Phlox subulata* Linn.

Explanation of the variability in the floral parts of Rondeletia odorata *Jacq.*

From the observation of the flowers it is clear that the different members of the floral whorl like the sepals, petals and the stamens are capable of independent numerical increase or decrease without one part growing at the expense of another. Another noteworthy feature is that the gynaecium behaves as a separate unit and is not affected by the changes in the other whorls.

The plant in question has been cultivated in the garden. No reference has been made of this plant by Hooker in his flora of British India or by the writers of the floras of the different Presidencies. Naturally it is to be expected that the plant is made to grow away from its native surroundings, and so cumulative action of the changed conditions of life under which the plant has been nurtured would have greatly contributed to the increase in the number of floral parts; or as is evident from the variation observed, The present species might have resulted from close inbreeding and is perhaps not yet fixed.

Summary

Six hundred and ninety three flowers of *Rondeletia odorata* Jacq. were examined and it was found that the number of calyx teeth and the corolla lobes vary; whereas the number of carpels is constant in all the specimens. The number of stamens also vary. It shows a distinct relation with the corolla lobes, but it showed very little correlation with the calyx teeth.

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LIFE-HISTORY OF *SANTALUM ALBUM* Linn.*

BY

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Introduction

The Santalaceae are mostly parasites on the roots and stems of other plants and occupy a place of special interest among the Dicotyledons. Since they are peculiar not only in their mode of life, but also in the unique development of their reproductive organs, they have attracted the attention of plant morphologists. Though a considerable amount of work on this group and allied families with similar morphological peculiarities has been done, their complete morphology and physiology are inadequately known.

The observations of the earlier writers on the reproductive organs are chiefly concerned with a general description of the embryo-sac. It was as early as 1836 that Griffith gave a description of the anatomy of the flowers and the morphology of the embryo-sac of *Santalum album* and the development of the embryo in *Loranthus,* in a paper read before the Linnaean Society of London. Decaisne, a few years later, read a paper before the Academy of Science of the French Institute, on the "Observation and Development of the pollen and the changes in the ovules of *Thesium*". In this paper, he refers to Griffith's discovery of the apical growth of the embryo-sac into the ovarian cavity towards the pollen tube in *Santalum album* and mentions the occurrence of similar apical growth in several other members of the Santalaceae—in *Nanadea, Myoschilas, Osyris* and less clearly in *Quinchamlium.* His interpretations, however, are not accurate in the light of later researches. In 1843 Griffith described the posterior elongation, before fertilisation of the three embryo-sacs of *Santalum album* and of only one embryo-sac of *Osyris.* In 1856 Hofmeister studied the various species of the Balanophoraceae and the Loranthaceae and described the development of the archegonium-like megasporangium and the embryo of the former and the puzzling "mamelon" of the latter. Further investigations of Hofmeister in 1857, greatly advanced our knowledge of the early stages in the seed of *Thesium* and on the floral organs of the Loranthaceae. Van Tieghem (1869) and Treub (1885) discovered that similar outgrowths from the embryo-sac occurred in the Loranthaceae, Olacineae and the Santalaceae and pointed out the affinity between the above families. Guignard (1885) published a paper on the Santalaceae, wherein he dealt at length on the development of both *Osyris* and *Thesium.* In the same year, Strasburger describing the embryo-sac of Santalum as normal, discussed the formation and later the disorganisation of the synergids. Jost (1888), Johnson (1898), Skottsburg (1913) and Billings (1932, 1933) have contributed much to our knowledge of the development of the megaspore and embryo of some of the members of the Loranthaceae. Ottoumiker (1920) published a paper on *Helosis guyanensis* (Rich) wherein he dealt with the cytology and development of the embryo-sac and the embryo. Modilewski (1928) worked on the embryological development of *Thesium intermedium* with a view to supplement the partly old and partly incomplete account of *Thesium.* Schulle (1933) working on the complete developmental history of *Thesium montanum,* discussed on the variations observed in the two species worked so far and reported the occurrence of tracheids in the nucellus and their relation with the chalazal haustorium.

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* The present investigation was carried on under the auspices of the Scientific Committee for Sandal Spike Investigation.

Thesis approved in partial fulfilment for the Degree of Master of Science in the University of Mysore.

MATERIAL AND METHODS

The material for this study was collected from plants round about Bangalore and at Hirehalli plantation. Flower buds of various sizes were collected. Chromo-acetic solution with or without Osmic acid and Bouin's fixative were used. The results that were derived by the use of Flemming's fixing solution gave good results in the study of microsporogenesis. For megasporogenesis and embryology, Bouin's gave good results. Sections were cut from 7-10 microns thick and stained in Heidenhain's iron-alum haematoxylin alone or with a counter stain.

DEVELOPMENT OF THE FLOWER AND FLORAL PARTS

The development of the floral parts is in conformity with that of *Thesium* (Schulle 1933), where the development of the lobes of the mamelon is more extensive than in *Santalum.*

MICROSPORANGIUM

In a transverse section, the staminal primordia appear at first oval in outline, consisting of a homogeneous mass of small meristematic cells covered by an epidermis. Very early in development, they become four-lobed.

At first the young sporogenous tissue is not readily distinguishable from the surrounding cells and cannot be traced back to the divisions of a single or more archesporial cells (Text Fig. 1 a). Later, they become noticeably larger surrounded by four to five layers of cells which separate it from the epidermis. Under the epidermis is a layer of somewhat swollen cells which with the epidermis persists as the wall of the mature locule (Text Fig. 1 d). Within this is the third layer composed of transversely elongated cells, which become compressed in later stages (Text Fig. 1 c). The tapetal cells abut on the sporogenous tissue. On account of the formation and growth of the cells, there is a corresponding increase in the size of the anther. Soon, however, the pre-meiotic divisions in the sporogenous cells are completed and the miscrospore mother cells enter upon their long period of growth.

The tapetal cells are marked out early in the development of the anther. They may be one to two cells in thickness. The single nucleus observed at first divides in a typical mitosis and the cells later become binucleate, trinucleate or tetranucleate. In some cases, the tapetal cells protrude into the sporogenous cavity.

MICROSPOROGENSIS

Resting nucleus. In the resting stage the microspore mother cells are polyhedral in outline and are easily distinguished from the surrounding cells by their large size and their deeply staining nucleus and cytoplasm. The cytoplasm stains uniformly. Within the membrane and continuous with it is a fine reticulum with chromatin aggregations at the points of intersection. These chromatin aggregations, however, do not suggest the prochromosomes. There may be one to three dark staining nucleoli with or without the bud-like projections (Text Fig. VI. a.). By the time the nucleus becomes active, only a single nucleolus is seen.

Leptonema and Zygonema. With the onset of meiotic prophase the nuclei show decided growth in size. The reticular threads become coarser and the large masses of chromatin become scattered along the threads. In zygonema they become more thread-like. Although the threads appear to be single, there are several places where parallelism is evident (parallelism of univalents).

Synizesis. The threads show signs of contraction from the nuclear membrane. They increase in length tending more and more towards a uniform thickness. Finally the chromatin threads are drawn into a tight knot and lie at one side of the nuclear cavity. The nucleolus may or may not be included in the knot.

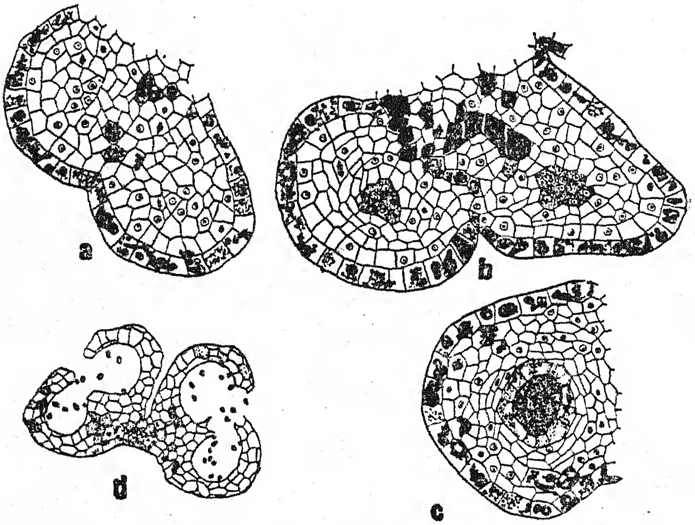
With the onset of this stage, the dense granular cytoplasm progressively becomes fibrillar in nature radiating centripetally. The cell wall as a whole shows signs of rounding off the corners (Text Fig. VI. b.). The nucleus remains in this condition for a long time.

Spireme. The commencement of this stage is marked out by the throwing out of loops from the synizetic knot. It is possible to observe the double nature and the twisting of the threads. Further loosening is much more gradual than the previous contraction stage.

The thread finally unravels completely and remains evenly spread in the nucleus.

Pachynema and *Strepsinema.* The threads segment and thicken. As the double threads condense they twist and loop over each other. There is not much increase in thickness of the double threads. The chiasmata established between the paired segments are faintly made out. Further condensation of the spireme continues and results in the shortening of the threads to form the bivalents.

Diakinesis. During early diakinesis the bivalents are long. The condensation continues giving a spiny appearance to the bivalents. The nucleolus shows signs of paling. Later smaller nucleoli are given off as buds from the larger nucleolus which disappear at about the time of the dissolution of the nuclear wall.



Text-fig. I.—(*a*) Cross section of two locules of an anther before archesporium formation showing homogeneous mass of cells. × 240; (*b*) Cross section of an anther locule showing the differentiation of the sporogenous cells in the centre. × 240; (*c*) Section of a single locule showing the differentiation in the wall layers. Tapetal cells are uninucleate. × 240; (*d*) Cross section of an anther at the shedding time. × 240.

In late diakinesis the bivalents occupy a peripheral position. Fibres make their appearance in the nuclear cavity. The nuclear wall disappears. The fibres increase and become multipolar. Finally they become bipolar. During the formation of the spindle fibres, the bivalents come to be arranged in the centre, where two to three chromosomes are surrounded by the remaining ones in the form of a circle (Text Fig. VI. c.). Thus the ten bivalents are arranged on the metaphasic plate.

Metaphase. The fibres are thick and prominent. They appear to be attached terminally to the ends of the chromosomes. Apart from the thicker fibres there are finer ones which are probably derived by the peculiar arrangement taken up by the cytoplasm enclosed within the spindles.

Anaphase. The separation of the chromosomes is more or less regular, except in very few cases where two or three chromosomes lag behind.

Telophase. Having arrived at the poles, the chromosomes are from the thicker fibres, there are finer ones which are probably condition for some time. Vacuolization begins. The nuclear membrane is formed. Further growth of the nucleus takes place.

Interkinesis. Contrary to the process involved in the division of the microspore mother cell nucleus, which extends over a long time, the succession of events followed in the daughter nuclei are very rapid. Usually the daughter nuclei divide simultaneously, except in some cases where one develops and the other increases enormously without division.

In this division the chromosomes are small and are arranged in a regular compact plate at the mature spindle stage. The spindles may lie either paralellel to each other or at right angles to one another or may lie in any intermediate position.

The chromosomes move as separate plates. The chromosomes reach the poles where definite nuclei are organised. The four nuclei are connected by a system of connecting fibres, which are inflated near their equatorial region. The daughter nuclei may not be all alike, since degeneration sets in.

Cytokinesis. The arrangements of microspores in a tetrad may either be bilateral or tetrahedral, depending on the disposition of the homoeotypic spindle.

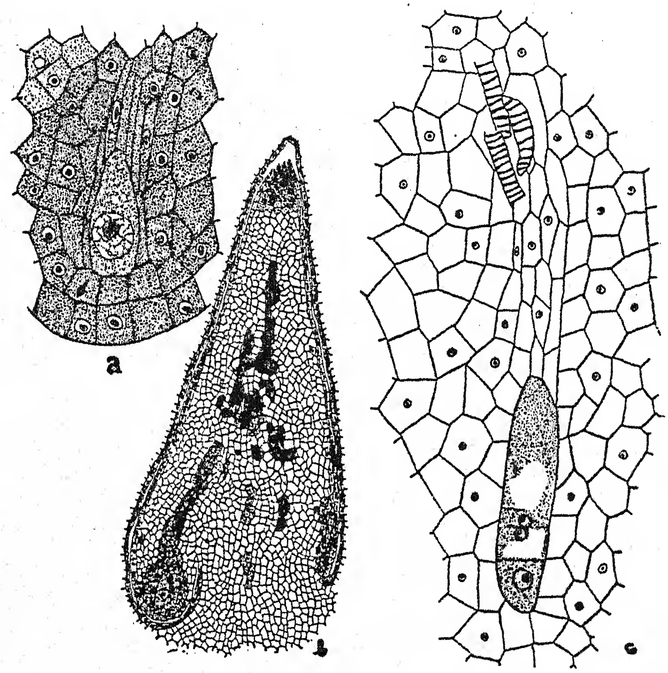
Small constrictions or furrows appear at the periphery of the cytoplasm, midway between each nucleus. These gradually progress inwards until they meet at the centre cutting the four nuclei apart from each other. The cytoplasm in the region of development of the furrows is less compact than in the other regions. Finally the individuals of the tetrad are liberated in the cavity of the anther.

In cross section the oval microspores are triangular. A thin intine and a smooth thick exine with three germinal pores at the corners are developed. At shedding time the pollen grains are uninucleate.

MEGASPOROGENSIS

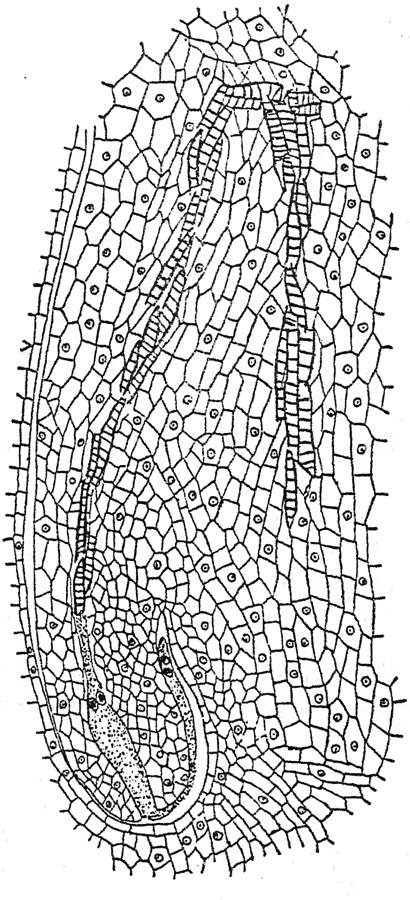
Very early in the development of the ovary and at the time the ovules are differentiated, one of the laterally situated hypodermal cells, in each ovule, is differentiated as archesporium. Occasionally two archesporial cells may be seen. The archesporial cell soon divides by a periclinal wall to form a parietal and sporogenous cell. The parietal cell, at times, divides by anticlinal and periclinal walls, so that the sporogenous tissue becomes deeply lodged. The ovule is naked.

At about this time, one or two rows of cells immediately surrounding the megaspore mother cell and two to three rows of narrow cells extending over a good length in the chalaza from the base of the mother cell become densely granular and take a deep stain (Text Fig. 2 a and b). At a later stage this granular nature of the cytoplasm disappears owing perhaps to the utilization of the material by the developing mother cell.



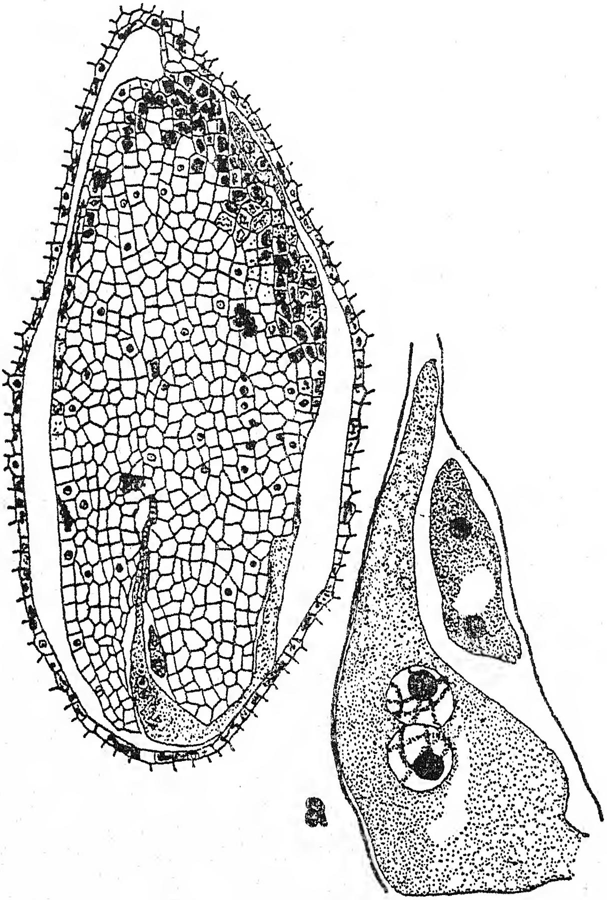
Text-fig. II.—(*a*) & (*b*) Megaspore mother cell showing the nutritive jacket and the conducting cells. (*a*) Part of the ovule highly magnified. × 144. (*c*) Linear tetrad. Three tracheids making their appearance, at this stage, is shown. × 2200.

The megaspore mother cell enlarges and elongates considerably, then undergoes two successive divisions to form a linear tetrad. By the time the tetrad is organised 2-3 tracheids make their appearance in the nucellus, a short distance from the chalazal end (Text Fig. 2 c). As further development of the embryo-sac proceeds, the tracheids develop in the region already marked out by the rich cytoplasmic cells, at the base of the embryo-sac. The cells with rich granular cytoplasm are transformed into the tracheary tissue observed at this late stage. The development of this tracheary tissue becomes complete by the close of the formation of the tetra-nucleate sac (Text Fig. 3). Only the lowest megaspore functions (Text Fig. VI. i.).



Text-fig. III.—Part of the section of the ovary showing the formation of the tracheary tissue at the close of the tetra-nucleate stage (reconstructed from 14 sections). × 160.

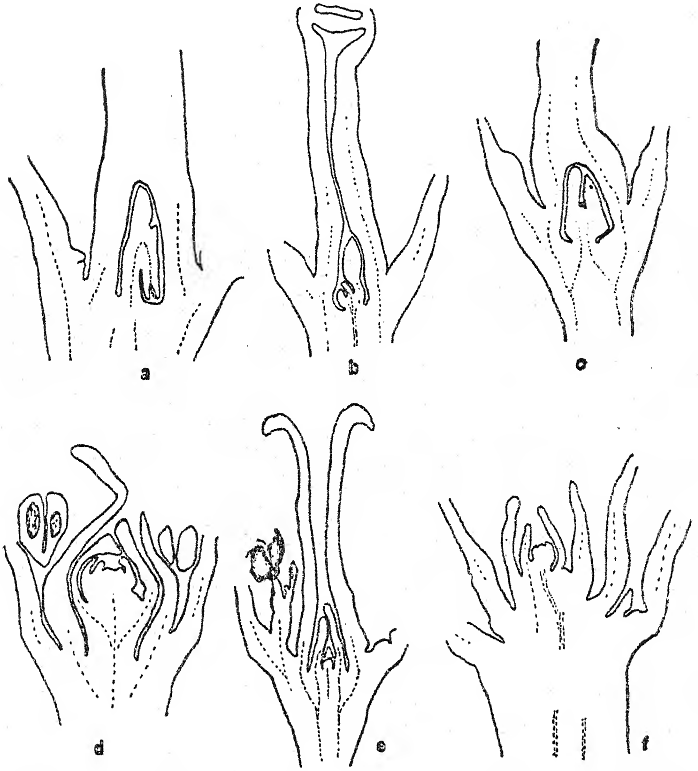
The nucleus of the functioning megaspore divides and the two nuclei occupy the two poles. The degeneration of some of the embryo-sacs becomes evident, with the enlargement and the division of the megaspore. This is always characterised by the increasing density of both cytoplasm and nucleus by plasmolysis and at times by vacuolization of the cytoplasm and the final collapse into a distorted strand in the centre of the cell. This disturbance occurs with increasing frequency throughout the various stages of the embryo-sac formation.



Text-fig. IV.—Four nucleate embryo-sac. The micropylar end has reached its maximum length. A two nucleate embryo-sac probably derived from one of the sister cells of the tetrad has degenerated. × 160. (*a*) The chalazal end highly magnified. × 1800.

Following the binucleate stage, the micropylar end of the embryo-sac shows signs of elongation. The chalazal end remains inactive, till some time later. The formation of four nuclei from the two is accompanied by divisions which are not remarkable except in the arrangement of the two spindles. The micropylar end of the embryo-sac grows almost straight, downwards in the ovule, then curves outwards in the ovarian cavity and grows up a short distance

(Text Fig. VI. j.). Coincidentally with the downward growth of the sac, the cytoplasm and the micropylar nuclei move to the tube-like elongation. The nuclei lie a short distance from the tip of the micropylar end. The tip of the tube is more or less pointed and stains more deeply than the lower region where the nuclei are found. This tetra-nucleate stage extends over a long period so that the short growth observed at the commencement of this stage, reaches the maximum length before the nuclear activity commences. Thus the micropylar end of the embryo-sac comes to lie almost very near the apex of the placenta (Text Fig. 4). During this growth in the ovarian cavity, the micropylar end of the embryo-sac, at times, is appressed to the placental wall and the cells of the latter get disorganised at the place of contact.



Text-fig. V.—*Phyllodes*: (*a*) Formation of the growing point in the placenta. Dotted lines indicate the vascular strands. (*b*) Later stage than (*c*). (*c*) The placental lobes are turned upwards in the formation of leaf primordia. (*d*) Partial phyllody. (*e*) & (*f*) The pistil is completely transformed into leafy structures while the anther locules are distorted.

Following this stage, the chalazal nuclei divide much earlier than the micropylar ones. The orientation of the spindles varies and the disposition of the antipodal cells depend entirely on them.

The antipodal cells are formed early and are ephemeral. They may either be arranged in a linear direction, or two of them may be arranged side by side over a lower one. In any case, the lowest antipodal cell is very much elongated and is pointed at the free end.

The formation of the mature egg apparatus will be over by about the time the fusion of the polars takes place. The upper surface of each synergid is horizontally notched owing to an indentation and presents a beak-like appearance. Associated with the beak-like extension of the synergids, the 'filiform apparatus' is developed. The filiform apparatus is a solid mass of conical shape which is traversed regularly by a number of minute striations, which arise from the basal part and converge towards the apex. The tip is blunt. The upper part of the synergids protrudes beyond the wall of the embryo-sac and thus, the indentation is just against the upper end of the broken wall. Small vacuoles are present at earlier stages but in mature synergid, there is a large vacuole at the base, over which the nucleus is lodged (Text Fig. VI. m.).

At the time the polar nuclei leave the poles a remarkable change occurs at the chalazal end. Simultaneous with the migration of the polar nuclei from the poles, the antipodals which mark the lowest end of the embryo-sac get separated from the rest of the portion. The blunt end continues its growth, past the antipodals leaving them to a side (Text Fig. VI. k. & l.). The tip of the tube is pointed, ensuring a more ready passage through the nucellus and the placenta. The penetration is effected by the disorganisation of the cells, by the tip of the tube. The tip of the tube derives its nourishment from the cells immediately surrounding it. Thus the growth of the tube brings it into the most advantageous position for absorbing food.

For convenience, this tube is designated the 'Haustorium'. The growth of the haustorium appears to be in some way influenced by the movement of the polar nuclei in the embryo-sac. The haustorium reaches the maximum upward growth, at the time of the approach of the polar nuclei. Then the tube bends on itself, in a way similar to the tracheids and continues its downward growth in a more or less winding manner till it reaches the base of the placenta (Text Fig. VI. l.). By the time the polar fusion is complete the growth of the haustorium stops short at the base of the placenta. It remains inactive till after fertilisation when the second phase of the activity of the haustorium commences. As noted above the antipodal cells begin to disorganise before the tube develops there by giving rise to an unusual condition of an enucleate haustorium.

The haustoria during their downward growth in the placenta become fused with each other so that a large cavity is formed in which the cytoplasmic tubes are lodged. Variation in the backward elongation of the sacs are found from the earliest to the latest stage.

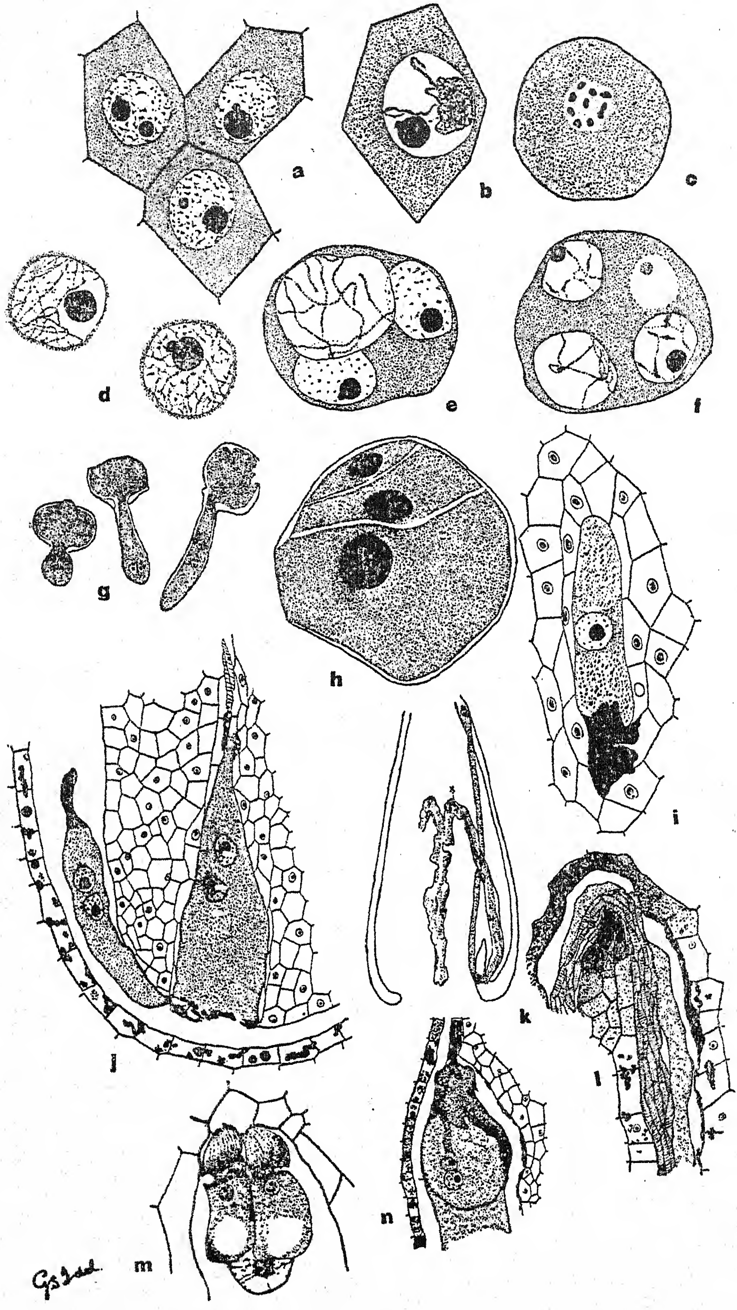
The embryo-sac at the time of the fusion of the polars consists of two synergids, below which there is a large egg nucleus, separated from the former and the main cavity of the embryo-sac by a thin wall. Below this is the long cavity of the embryo-sac. More or less, very near the base, is the large nucleus still showing signs of the fusion of the polar nuclei. At the base of the embryo-sac proper are the distorted remains of the antipodals. The haustorial tube is found further down in the placenta.

Fertilisation. The germination of the pollen grains on the stigmas does not take place readily. A few hours after pollination, the pollen grains germinate and grow along the side of the papillae, to which they may be closely appressed. The growth of the pollen tube in the conducting canal cannot easily be followed. The divisions of the pollen grain nucleus occur in the pollen tube. The pollen tube pierces between the synergids, causing them to disorganise. The pollen tube, after getting into the egg cell, approaches very near the egg nucleus. The tip of the tube bursts and the contents are discharged. The egg and the male nuclei remain together for a short time. At the time of fusion, the reticulum of the male nucleus is coarser than that of the egg nucleus.

The chalazal haustorium which is passive till after fertilization, begins active growth. This is perhaps due to the activity of the chalazal or the haustorial nucleus. The growth of the haustorium proceeds towards the carpellary vascular strand in the tissue of the base of the ovary. Finally, the tip of the haustorium comes to lie in a sort of cup, formed by regular strands of cytoplasmic cells, whose other ends are in direct contact with the branches of the central carpellary strand. They appear as dark staining cells, more or less radiating from the apex of the haustorium. Somewhat later, the thickening of the walls of some of these cells to form tracheids are seen.

Endosperm.. The activities of the fusion-nucleus precede fertilisation. The first sign of the activity becomes apparent at the time of the penetration of the pollen tube through the synergids. By the time the first male nucleus is discharged into the egg cell the first mitotic figure is seen in the fusion-nucleus. The second male nucleus remains as a disorganised mass in the pollen tube. Perhaps the penetration of the pollen tube between the synergids stimulates the fusion-nucleus and thus its activity commences. By the time syngamy is completed, free endosperm nuclei are scattered in the bend of the embryo-sac.

The first division of the fusion-nucleus divides the embryo-sac into two chambers—the small micropylar and the long chalazal, which includes the haustorium. The chalazal nucleus, without further division functions as the haustorial nucleus; while the micropylar nucleus continues its activity by the free nuclear divisions. When the nuclei are freely distributed in the micropylar chamber, wall formation sets in, commencing from the embryonal side. During early wall formation, two or three nuclei may be enclosed in a single cell but sooner or later each endosperm cell becomes uninucleate. Now the endosperm tissue enlarges at the expense of the adjacent



Text figure VI.—(*a*) Three adjacent microspore mother cells. One or two nucleoli with or without bud-like outgrowths are seen. × 900. (*b*) Spireme emerging from synezesis with evidence of paired threads. × 450. (*c*) Polar view of a heterotypic equatorial plate showing 10 chromosomes. × 900. (*d*) Microspore mother cells showing the crystalloid and the vacuoles in the nucleoli. The buds are darker than the nucleolus proper.

tissue and pushes the embryo to the top of the ovarian cavity. On account of the continued development of the endosperm, the placenta along with the developing embryos, is pushed to a side opposite the region of the development of the endosperm tissue. Thus, the placenta is separated from the base of the ovarian cavity and the endosperm tissue comes to lie in direct contact with the broken end of the haustorium (Text Fig. VII. d.). When the endosperm is fully formed the embryo comes to lie at the base of the style.

Embryo. After fertilisation the egg forms a wall. The embryo remains unicellular and undifferentiated for a long time, as in many other parasites. The first division is transverse to the long axis of the embryo-sac, separating a large proximal suspensor cell and a small terminal pro-embryonic cell (Text Fig. VII. a.). It is at this stage that the first wall formation in the endosperm is observed. During the next division a vertical wall is formed in both the cells (Text Fig. VII. b.). The third division in the embryo formation occurs transversely in the terminal cell (Text Fig. VII. c.). The further divisions follow no regular sequence. The divisions are more in a vertical plane, so much so the conical embryo becomes cylindrical. The proximal suspensor cells appear to remain without any divisions till some more time. The embryo is free in the endosperm cells.

After some more divisions in the embryo, the first division in the suspensor cells takes place. The next stage results in the formation of irregularly elongated suspensor cells, which merge into the cells of the embryo. The embryo gets connection with the endosperm after the formation of the suspensors (Text Fig. VII. d.). The dermatogen is early differentiated.

Further development of the embryo is rapid. Slight depression arises in the centre of the flattened end of the embryo. The parts surrounding this depression grow faster to form the primordia of the cotyledons. Normally two cotyledons are developed but the development of three cotyledons is not of a rare occurrence (Text Fig. VII. f.).

The primary root lies with the apex in contact with the suspensor (Text Fig. VII. e.). It is not possible to make out clearly the relation of the tissues of the root to the other parts of the embryo.

As no integuments are developed and as the embryo-sac comes out of the micropyle, the carpellary tissue becomes the seed coat. In the mature seed there is a thin pericarp, thick and fleshy endocarp,

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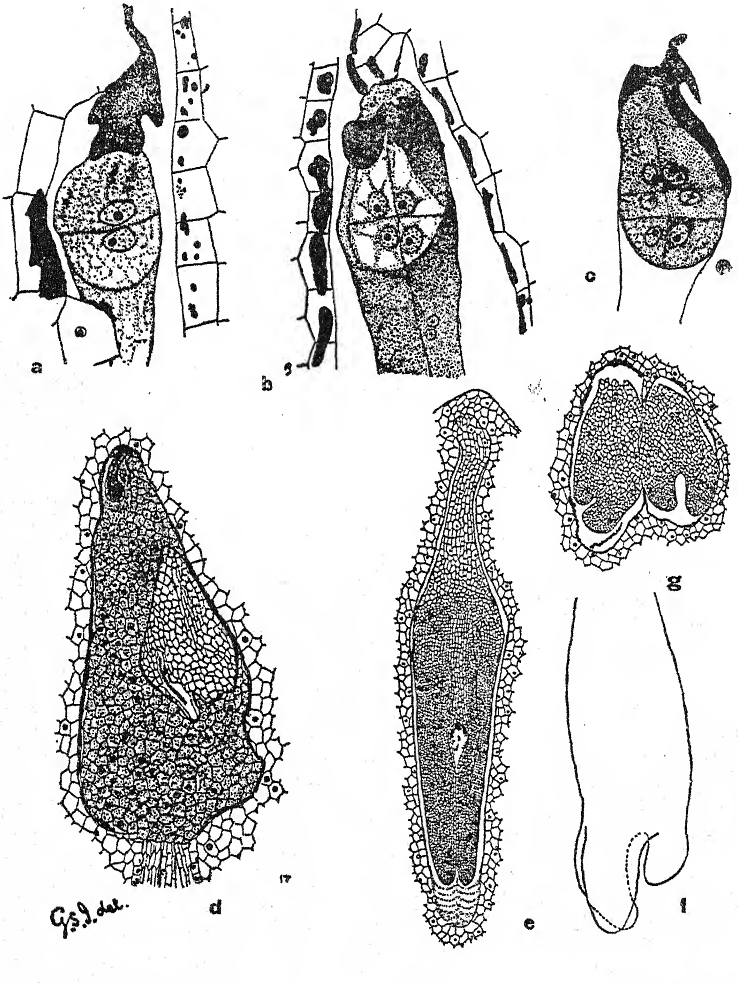
× 900. (*e*) & (*f*) Abnormal development in microspore formation. In one, (*e*), the second division of one of the daughter nuclei is suppressed. × 900. (*g*) Germination of pollen grains in artificial cultures. × 215. (*h*) A. three nucleate pollen grain from an anther of the flowers of a partially spiked tree. × 900. (*i*) Megaspore with disorganised sister cells. × 200. (*j*) Normal four nucleate sac. The micropylar end has pierced through the micropyle of the ovule. The micropylar nuclei are far behind the tip. × 450. (*k*) Longitudinal section of the ovary showing the reconstructed embryo-sac. The two haustoria from two embryo-sacs are represented. × 100. (*l*) Portion of the bend, x, highly magnified to show the disposition of the tracheids and the haustorium. × 450. (*m*) Egg apparatus, showing the notches and constrictions of the synergids. × 300. (*n*) Male nucleus in contact with the egg nucleus. The pollen tube still persisting in the egg cell. ×300.

and a hard mesocarp. The mesocarp consists of 5-7 layers of stony cells. The germ pore is developed at the base of the style and perhaps, the canal in the style forms the pore through which the radicle comes out.



Text figure VII.—(*a*) Two celled embryo. × 300. (*b*) Four celled embryo. The synergids appearing as dark masses. × 300. (*c*) Six celled embryo. × 300. (*d*) Gradual collapse of the placental tissue owing to the development of the endosperm in the ovarian cavity. Embryo is pushed to the base of the style. × 120. (*e*) Mature embryo with cotyledons. Root cap is formed at the base of the suspensor. × 40. (*f*) Diagramatic representation of a tricotyledonary embryo. One cotyledon is much smaller than the other two. (*g*) Two mature embryos developing in a single ovule. × 80.

Abnormalities. Many cases have been reported where several primary embryo-sac cells derived from different mother cells of a single ovule start forming the embryo, but as to the twin sacs few examples have been given. Both the types occur in Santalum album. The developmental stages of the double embryo-sacs could not be followed, owing to their rarity.

Degeneration. Degeneration in the stamens may begin after synezesis and may go on until the organisation of the pollen grains. In rare cases, the whole locule may show signs of disorganisation. In the second division of some of the microspore mother cells, the nuclei never divide after interkinesis but swell up (Text Fig. VI. e.).

Venkata Rao (1933) has reported a variety of *Santalum* wherein the anthers are syngenesious. They are thin and papery. The connective is broad. The microspore mother cells are not usually formed, but, when formed, they are not more than about 5-6. The female sex-organs are normal in development. Thus, we find, that except for the development of a few fertile pollen mother cells in a very small number of anthers in the flowers of a tree, the flowers may be practically considered as unisexual.

One, two or three embryo-sacs within a single ovary advance very far in their nuclear contents and not in their micropylar elongation. It is characterised by darker staining and increasing vacuolation of the cytoplasm, the nuclei becoming deeply granular and staining as a homogeneous mass. Fertilisation may be effected in all embryo-sacs but only one embryo develops.

Phyllody. In *Santalum* malformations in the flowers are met with among the spiked plants. In severe attack of the disease, the sporangia are completely replaced by vegetative organs. In the early stages of the disease, the pollen sacs appear more or less completely developed, but with distorted pollen grains. In certain cases (Text Fig. VI. h.), the uninucleate pollen grains of the healthy plant divide giving rise to two male nuclei and a single tube nucleus. The stamens, when completely malformed, are transformed into leaves.

In conformity with the modifications above noted, the pistils are also subjected to such transformations. The ovules are replaced by simple leaves, if the malformation has started at a period when the primordia of the ovules are not developed (Text Fig. 5). Similarly, the carpels enlarge and inflate and finally a foliage leaf appears for each carpel. Thus, "The sexual potency has been enfeebled while the vegetative has been increased through nutrition." Phyllody in *Santalum* is perhaps, a case of reversion.

DISCUSSION

The question of the correct interpretation of the elongated floral axis met with in the flowers of Santalaceae, Myzodendraceae and Loranthaceae has been a puzzling one. Hofmeister (1859) working on *Loranthus europaeus,* thought it to be a naked ovule in which several groups of archesporial cells are present. Treub (1882), however, advanced the view that the mamelon is a growth of the floral axis, in which separate nuclei represent the rudiments of ovules. Johnson (1889) designated similar structures in the *Myzodendron* as ovarian papillae. In the forms worked out in the Loranthaceae by Hofmeister (1859), Treub (1882), Buillon, York (1913) and Billings (1933) the embryo-sacs are seen to be derived from the laterally developed archesporia in the undifferentiated floral axis. Guignard's (1885) observations on *Thesium* has brought to light the development of a laterally developed embryo-sac which, at a later stage, bends down towards the placenta. A similar condition exists in *Osyris,* but the elongated lobe observed in *Thesium* is turned upwards towards the apex of the mamelon. In *Phoradendron,* according to Billings (1933) the embryo-sac is seen to arise laterally, but more directed towards the apex. *Santalum,* while showing a development similar to that of Thesium, differs from it in the absence of extensively developed lobes.

On the basis of a comparative study of the development of the mamelon in the above families, York (1913) remarks that there is a strong similarity between the megasporangia of *Dendrophthora, Thesium,* and *Santalum* and further suggests that this similarity of development of megasporangium and the female gametophyte might be taken as indicative of a phylogenetic relationship.

Four nucleate embryo-sacs developing somewhere about the central axis, laterally, in *Santalum,* lend further support to the correct interpretation of the nature of the mamelon. These embryo-sacs are probably derived from archesporial cells which are separated by a few sterile cells, from the usual archesporium, developing in the lower lobes to form the normal embryo-sac. The present investigation lends strong support to the correctness of Treub's view regarding the nature of the mamelon.

In almost all the families above referred to, there is no development of the appendages of the placenta which could be called ovules. It is only in a few cases like *Dendrophthora, Loranthus sphaerocarpus, Thesium* and *Santalum* that lobes are put forth from the placenta which are considered to be of the nature of the ovules. Definite integuments are not made out in any members worked so far. Warming (1878) working on *Thesium,* reported the existence of the vestiges of integuments which are represented by the epidermal cells. He traced their origin to the repeated tangential divisions of the epidermis. Goebel views the depression of the tip of the ovule as the portion of the micropyle. Schulle (1933) remarks that as it is not capable of being observed externally in that the 'integmental initial' does not develop further and as it does not contribute to the formation of the seed coat it is spoken of as a naked ovule. Thus the opinion put forward by Goebel and later contended by Schnarf that the Santalacea also has indication of thick integuments is not supported by later researches. In *Santalum* the ovule is naked.

The micropylar elongation of the embryo-sac, in its early stages of development have been observed in almost all parasitic plants, so far worked out—*Osyris* (Guignard), *Dendrophthora* (York), *Phoradendron* (Billings) and *Santalum* (Griffith). In *Dendrophthora* and *Phoradendron,* the chalazal end enlarges and advances upwards while the micropylar end makes its way in the carpellary tissue. This growth in *Dendrophthora* (York) is regarded in part as a response to chemotactic stmuli. In Myzodendron the embryo-sac is described as stationary until after fertilisation. There is no micropylar elongation. After fertilisation the micropylar portion of the embryo-sac in *Thesium montanum* (Schulle) bulges enormously and passes out of the ovule, even after the pulling action of the nucellus tissue. As a result of this, the membrane of the megaspore is invariably ruptured. This effects the inversion of the wall and the egg apparatus appears to be shifted towards the placenta and the embryo comes to occupy a complete inverted position. One point of difference between the Loranthaceae and Santalaceae in the elongation of the micropylar end, is that while in the former the growth takes place in the carpellary tissue, the growth in the latter is in the ovarian cavity.

In *Loranthus sphaerocarpus* (Treub) and *Dendrophthora* (York) dark staining tissue of a few cells thickness surround the young sporophyte and nourish it. Schulle (1933) describing the structure of the placenta in *Thesium montanum* says that it is formed out of regular layers of longitudinally stretched parenchymatic cells which surround a central conductive strand. Its ultimate changes are not known. They were at first fused or grouped themselves into cells rich in plasma, transforming themselves into tracheids. The position of these tracheids is entirely irregular. Likewise, rich cytoplasmic cells surround the developing megaspore mother cell in *Santalum.* Later some of these cells get transformed into tracheids and are replaced by the haustorium. Thus it can be seen that the conducting tissue is gradually replaced by a more effective mechanism as demand for nutrition increases. The rich cytoplasmic cells can be considered as tapetal cells purely in a functional sense.

Frye (1902) while discussing the nature and significance of the occurrence of tracheids in the nucellus in *Asclepias,* has supported Benson's view, that the presence of the tracheids in the nucellus, is an indication of a degenerate chalazal vascular strand once extending into the nucellus. The presence of regular vascular tissue extending between the chalaza and the carpellary strands, in the phyllodes of *Santalum* where the embryo-sacs are seen to suppress their growth, after the attack of the disease, might perhaps, suggest an ancestral type to which the normally developing chalazal tissue reverts occasionally.

Griffith in his observations on the Santalaceae, figured and described the branching of the chalazal portion of the embryo-sac of *Santalum* and mentioned that it behaved like a pollen tube. The present observations do not corroborate his description.

According to Goldfus, the antipodals which burrow into the chalaza have a nutritional as well as a conductive function. In

Santalum album the antipodals are conductive rather than nutritive. The ephemeral antipodals observed in the present material, are commonly met with in plants where chalazal haustoria develop. In *Thesium* the disappearance of the antipodals occurs very early, which in *Osyris* is late. Modilewski (1928) assumed that in lower portion of the embryo-sac, in isolated cases, no formation of the four nuclei takes place, but probably only two nuclei are present of which one functions as the polar nucleus and the other degenerates rapidly. Such irregularity in the antipodal region was observed by Guignard also. In *Santalum* they begin to degenerate very soon after their formation.

Coulter and Chamberlain remark that beaked synergids are associated with narrow and long micropyles and are of assistance in the progress of the pollen tube. The deep notch described for the 'filiform apparatus' in *Santalum* by Strasburger (1885) is in conformity with the present observations.

Strasburger remarks that there is only a single synergid in *Santalum album* (Coulter & Chamberlain, 1903). The observations made by the present writer clearly indicate the existence of two synergids with well developed 'filiform apparatus' and one egg cell. The same author (1885) while describing the embryo-sac of *Santalum* as normal, says, that the pollen tube passes between the synergids disorganising only one of them, while the other remains transparent. The writer, however, found that both the synergids take on a dark stain, the moment the pollen tube commences to pass between them.

The change in the shape of the haustorial nucleus observed in the plant under report, is also observed in *Thesium montanum* (Schulle, 1933). The hypertrophied nucleus in the haustorium shows an entirely similar change as the nucleus of glandular cells, observed by Tischler and others.

According to Guignard (1885) the embryo of *Osyris* has no suspensors. A similar condition is observed in *Viscum* (Pisek) and *Arceuthobium* (Johnson). The development of the embryo in *Thesium* is reported to be different by different workers. According to Hofmeister (1858) the embryo forms a small suspensor. On the contrary, according to Guignard (1885) suspensor is absent, while Schulle (1933) is of the opinion that the fertilised egg cell itself elongates and then becomes divided by a wall at its base to form a pro-embryo and a suspensor cell. The latter does not develop further but merely undergoes degeneration. Schulle (1933) further remarks, that "it must however, remain open, whether the development of the embryo takes place in the manner sketched above or whether the egg cell becomes completely utilized towards the formation of the embryo, as assumed by Guignard." Perhaps, there is a gradual reduction in the formation of the embryo—a transitional form with small suspensors as *Thesium alpinum* and *Thesium intermedium* (Hofmeister), between *Thesium montanum* with early degenerating suspensor and *Thesium divaricatum,* where the suspensor is completely lost. The mature embryo in *Santalum* is massive with a well developed suspensor.

Strasburger (1885) reported a true case of polyembryony in *Santalum album.* As far as the present investigation goes, such a case has not been met with. On the other hand, cases of what may be termed 'false' polyembryony have been observed where two embryo-sacs have been found lying side by side and developing fully. These embryos might have been developed either from two megaspores of the same tetrad or from two different embryo-sacs of different tetrads in the same ovule. In the germination of the seeds two seedlings with separate radicles have been observed. Thus, it becomes evident that the variation in the development of the reproductive parts, observed in *Santalum,* is due to its primitive condition and not to its parasitic mode of life.

The cause of degeneration is not known. According to some investigators like Bradlmy, it is the faulty nutrition that is responsible. Strasburger thought that sterility is the result of excessive mutation; while Jeffrey is of the opinion that sterility is the result of hybridisation. Gartner thinks that degeneration in the stamens and ovules are caused by the inherent tendency in the species to become dioecious. Since some of the members of the Santalaceae are unisexual, and since degeneration in the reproductive structures of *Santalum* is repeatedly observed, it may be opined that sterility in *Santalum* may lead to the unisexual nature of the flowers.

Summary

1. The development and the formation of the microspore mother cells is normal. Ten bivalents are counted in the metaphasic plate. Degeneration and consequent sterility is observed. Cytokinesis occurs by furrowing.

2. In megasporogenesis, the hypodermal archesporial cell, after a single division, forms a parietal and a sporogenous cell. A nutritive tissue is differentiated early around the latter. A typical linear tetrad is formed. The chalazal megaspore develops. Two or three tracheids make their appearance at the chalazal end.

3. The binucleate stage is typical. The micropylar end of the embryo-sac pierces through the epidermis and grows up into the ovarian cavity.

4. During the tetranucleate stage, the tracheids get well organised between the base of the placenta and the chalazal end of the embryo-sac.

5. After the third division, an eight-nucleate sac is formed, which is in form of the letter *I.*

6. The antipodals disorganise as soon as they are formed. The blunt chalazal end grows up into the placenta in relation with the tracheids and finally, the tip comes to lie at the base of the placenta.

7. There is no double fertilisation. The fusion nucleus divides before syngamy. The fertilised egg after a period of rest divides.

8. The first division of the fusion nucleus results in a two chambered sac, the longer antipodal which includes the haustorium and the short micropylar one in which the endosperm develops.

9. The chalazal tube or the haustorium continues its second phase of activity and finally, its apex comes to lie very near the carpellary strand.

10. The first wall in the embryo is transverse. Suspensor is differentiated later.

11. More than two cotyledons may develop.

12. Twin embryos occur frequently.

13. Degeneration in the microsporangium and in the embryo-sac is observed repeatedly.

In conclusion, the writer wishes to acknowledge his indebtedness to Dr. M. A. Sampathkumaran, under whose direction the work was carried out in the Botany Laboratory, Central College, Bangalore, and to Mr. M. J. Narasimhan, Mycologist, Department of Agriculture, Bangalore, for kind encouragement and suggestions.

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CYTOLOGICAL STUDIES OF *ARGEMONE MEXICANA* Linn.

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Introduction

Argemone mexicana Linn: is a naturalised weed found during the winter in Bengal. It is gregarious in habitat and is the only representative of the family *Papaveraceae* in these parts.

Schnarf (9) has given a comprehensive account of the work done on the embryology of various members of the family Papaveraceae and it need not therefore, be repeated here. Until recently *Argemone mexicana,* had not attracted the attention of either the morphologists or cytologists. Joshi (5) has described the morphology of the plant and has given an account of the anatomy and morphology of an abnormal plant of the same species. He has also described (6) its megaspore formation and embryo-sac. The present author and Banerji (1), in a short note, have since given an outline of the process of development of the female gametophyte and have also determined the haploid chromosome number of the plant.

Material and Methods

The material used in this investigation was obtained from plants growing in the University Experimental Gardens. The material was fixed in the field on sunny days between 12 noon and 4 P.M. Various fixatives were tried of which Nawaschin's, Fleming's strong and Allen's modified Bouin's fluid gave the best results. A suction pump was always used to ensure rapid penetration of the fixing fluid. After fixation the material was washed, dehydrated and finally cleared in the usual way. The material was embedded in paraffin and microtome sections 8, 10, 12 or 14 microns thick were cut. Haidenhain's iron-alum hæmatoxylin and Newton's iodine gentian violet were the stains chiefly used.

Megasporogenesis

The gynoecium of *Argemone mexicana* is composed of five syncarpous carpels. Generally a number of spines occur in a single row on the ovary but these are not placed exactly on the central ridge of each carpel. The stigma is capitate and coloured bright-red in open flowers. Microscopic sections show that the stigma is covered by short unicellular hairs. The numerous ovules are borne on the parietal placentas. At first they appear as minute papillae and finally become anatropous.

The primordia of the integuments make their appearance at a very early stage. Generally the primordium of the inner integument is noted first. By this time a single archesporial cell differentiates out in the hypodermal layer of the nucellus. But two archesporial cells have sometimes been noted (Text-fig. 1). It very soon cuts off a parietal cell above and then functions as the megaspore mother cell (Text-fig. 2). The megaspore mother cell considerably increases in size before division. Before the heterotypic division takes place the inner integument overtops the nucellar tissue while the outer integument remains at a slightly lower level. Both the integuments at this stage are 2-3 cell layers thick. It is interesting to note that the outer cells of the outer integument are comparatively larger than the inner cells. This condition has also been noted by Vilcins and Abele (14) in *Papaver Rhoeas*. The heterotypic division is normal. A cell wall is laid down in the centre after the completion of the division and dyads are formed. The homotypic division soon follows. The homotypic spindles are generally arranged parallel to one another but in a few cases an oblique orientation of the upper spindle has been noted. This, as suggested by Joshi (6), gives rise to "T"-shaped tetrads. After the completion of the homotypic division, four megaspores are formed and these are generally arranged in a linear direction (Text-fig. 5). The upper three megaspores invariably degenerate while the last one functions. Degeneration proceeds from above downwards, although the second or third megaspore has been observed to degenerate first in some ovules. The chalazal cell is always functional. At this stage the megaspores appear to be deeply buried in the nucellar tissue due to the rapid divisions of the wall cells.

The functioning megaspore increases in size and becomes binucleate. The degenerating megaspores form a black mass at the top (Text-fig. 6). Degeneration of the surrounding nucellar cells is first noted at this stage. By the division of the two nuclei a 4-nucleate embryo-sac is produced which is considerably larger in size (Text-fig. 7). The vacuole noted at the centre of the embryo-sac at the two-nucleate stage also increases in size. The mature embryo-sac is eight-nucleate and is composed of one egg, two synergids, two polars and three antipodals.

The structure of the fully differentiated embryo-sac has already been described (1). It needs only be pointed out that the synergids are pear-shaped in appearance and have prominent vacuoles at their

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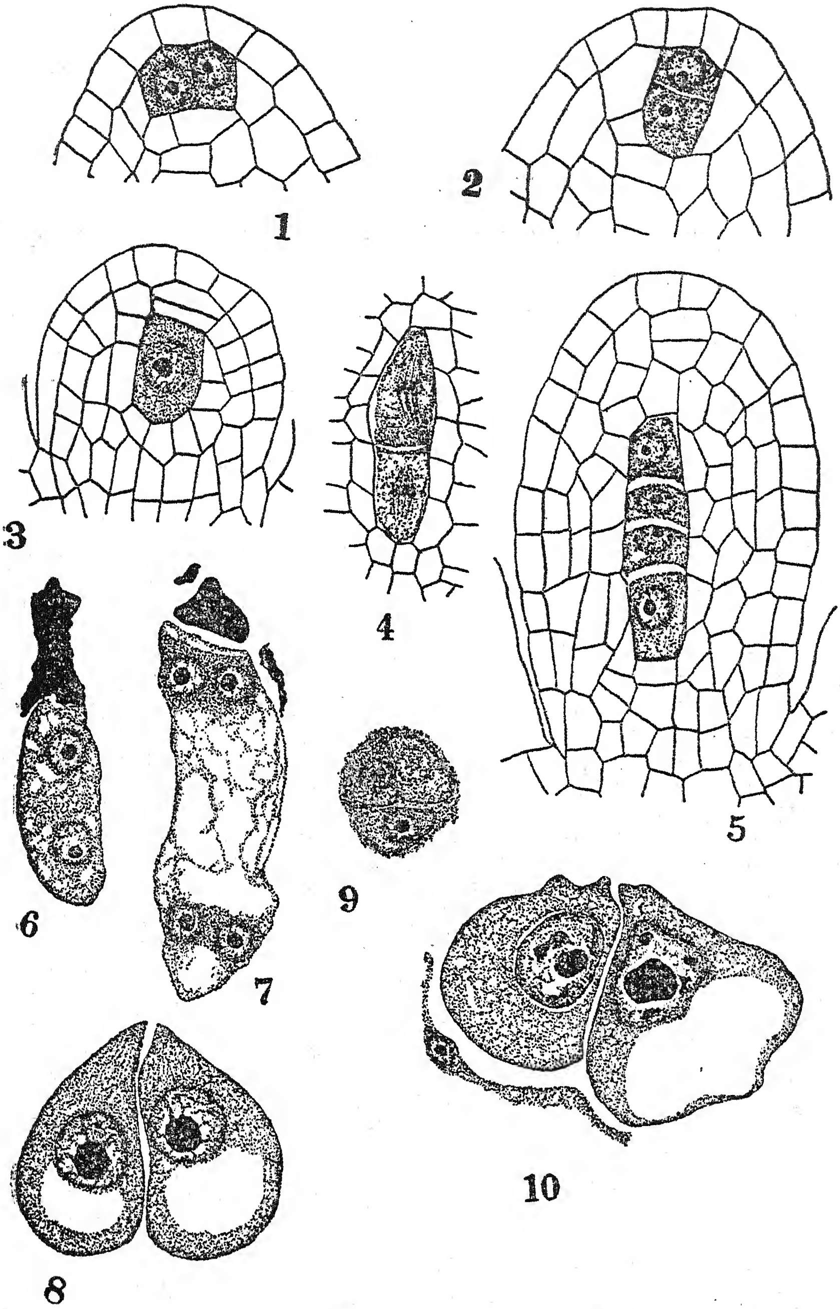
stage of development; Fig. 10. Mature antipodals. Two are only seen in the section. Compare the size of the antipodals with that of a nucleus of the endosperm lying in the peripheral layer of cytoplasm. Note also the deep staining masses appearing in the nuclei of the mature antipodals and the large basal vacuole in one of the antipodal cells.

(N.B.—Combination of lenses: Leitz Objective No. 7 and Ocular 10× = × 850 approximately.)



Text figs. 1—10. Cytological studies of *Argemone mexicana* Linn. × 850.

Fig. 1. Two hypodermal archesporial cells have differentiated out in the nucellus; Fig. 2. Periclinal division of an archesporial cell forming the primary wall cell and the megaspore mother cell; Fig. 3. The wall cell has divided again periclinally and the megaspore mother cell enlarging; Fig. 4. Homotypic divisions; Fig. 5. Normal, linear tetrad; Fig. 6. Binucleate embryo-sac just formed with the disintegrated megaspores on its top; Fig. 7. 4-nucleate embryo-sac with the remnants of the disintegrated megaspores; Fig. 8. Mature synergids with basal vacuoles; Fig. 9. Polar view of the antipodals in early

bases (Text-fig. 8). No filiform apparatus has been noted. The nucleus of the egg-cell is situated at the top and the vacuole lies at its base. The antipodal cells are nearly as large as the synergids but very soon increase in size (Text-figs. 9 & 10). The structure of the antipodals agrees with the description given by Joshi (6).

Microsporogenesis

Early stages of meiosis in P.M.C.: In the early stages of meiosis, the pollen-mother-cells are polygonal in outline and fit tightly together within the anther loculus. The nucleus is comparatively large, somewhat spherical in shape and possesses a well-defined nuclear membrane. It usually lies in the central part of the cell.

In the resting stage of the nucleus all the stainable material appears to be lodged in the nucleolus and the nuclear cavity is filled with faintly stained and indistinct strands of material of granular appearance. Under low magnification it looks as if there is a 'halo' around the nucleolus but the slides, which are comparatively deeply stained, show under oil-immersion that there is no clear space around the nucleolus, and the indistinctly stained nuclear reticulum merges gradually towards the nucleolus covering it from all its sides. The preparations which are more deeply stained show also that the faintly stained reticulum shows some stained 'net-knots' here and there in the nuclear cavity (Pl. XII, Fig. 1). The nucleolus is deeply stained and spherical in shape. It gradually occupies the centre of the nucleus and not more than one is seen in each case. The nuclear wall, though well defined, is very thin.

With the initiation of meiotic activity the nucleolus gives out one, two and sometimes three bud-like protuberances of variable sizes. The protuberances are round in shape and their sizes are variable. They gradually get detached from the nucleolus and travel from the nucleolus towards the periphery. Buds just cut off are generally larger in size but smaller ones are also observed (Pl. XII, Figs. 2, 3 & 4). As these pass on to the peripheral region, they are fragmented into smaller ones. Along with this process the lightly stained reticulum gradually becomes well-differentiated. The gradual increase of chromaticity in the linin thread following the fragmentation of these buds is clearly evident in different preparations. In certain preparations the reticulum has been observed to be connected with the nucleolus. The position of the nucleolus at this stage is variable, it lies either at the centre or near about the periphery of the nucleus.

From these indistinct linin frame-work the leptotene threads gradually differentiate out. They are very thin and delicate, but better organised. No parallelism of the leptotene threads can be detected at this stage except some chance associations. In destained preparations, vacuoles have been observed in some nucleoli (Pl. XII, Fig. 5).

The leptotene threads slowly recede away from the peripheral region from all the sides of the nucleus and ultimately a condensed knot is formed lying at one side in the nuclear cavity, where it is impossible to trace the continuity of the spireme for any distance. At first the threads gradually become thickened and more prominent. The nucleolus lies either entangled within the knot or may lie outside it (Pl. XII, Fig. 6), but always in close contact with the knot. Sometimes the nucleolus with a papillate process (bud) is seen but no connection with the spireme thread is, however, noted in any case. When the threads gradually open out, they are found to be beaded and comparatively thicker. The double nature of the threads is evident at this stage (Pl. XII, Fig. 7). The duality of the threads gradually becomes more prominent and is specially evident at the cut-ends of the spireme.

When the uncoiling is complete, the whole of the nuclear cavity is occupied by the spireme, which is continuous and shows the duality of the thread throughout its entire length. The pollen mother cells round off at this stage and begin to separate from one another. The irregularly coiled threads become thickened and the pachynema stage is reached (Pl. XII, Fig. 8). The duality of the pachytene threads is quite evident. 'Second contraction' was not observed and the pachytene thread breaks up into definite segments to give rise to the bivalent chromosomes. Gradually the segmented threads shorten. These segments are the forerunners of bivalent chromosomes. Chromatin condensation and contraction take place further giving the bivalents a firm and definite outline (Pl. XII, Figs. 9 & 10). When the bivalents are completely organised, they take up a peripheral position. The chromaticity of the nucleolus is gradually lost and at diakinesis the nucleolus disappears (Pl. XII, Fig. 11).

The sharp and definite outline of the nucleus is lost during the late diakinesis and the nuclear membrane becomes obscure. At a slightly later stage the clear nuclear cavity becomes filled up with a fibrillar substance from which a multipolar spindle is organised. The continuous straightening and converging of these fibres results in a bipolar spindle. The fibres which are connected with the chromosomes are more prominent than the rest. The stage of spindle formation passes off rapidly (Pl. XII, Fig. 12).

Heterotypic division: In the heterotypic metaphase the bivalents arrange themselves on the central region of the spindle. They are very small and are more or less of the same size and shape. A polar view of the equatorial plate shows fourteen ($n=14$) bivalent chromosomes (Pl. XIII, Fig. 13). The cytoplasm surrounding the spindle is very granular.

The bivalent chromosomes after disjunction gradually move towards the poles. The univalents are seen to be attached terminally by a group of spindle fibres (Pl. XIII, Fig. 14). The movement of the univalents is generally quite regular but sometimes 'laggards' have been noted. The laggards eventually reach the poles and none of them are cast out at the time of the reorganisation of the daughter nuclei. On reaching the poles the chromosomes clump together and their identity is lost for a time but they soon loosen out. An interphase stage is found in which the daughter nuclei become organised and the chromosomes lie scattered inside the nuclear cavity. They are seen to be connected with one another by fine elongated thread like processes (Pl. XIII, Fig. 15). The chromosomes gradually elongate and the anastomosing of fine fibrillae become more prominent. The nucleolus reappears and the daughter nuclei become oval in outline (Pl. XIII, Fig. 16). The spindle fibres vanish at the late interkinesis stage. A deeply stained cytoplasmic region is observed to appear between the two daughter nuclei which disappears subsequently. Vilcins and Abele (14) also noted the presence of similar cytoplasmic differentiation in *P. Rhoeas* at this stage.

Homotypic division: During the prophase of the homotypic division enlargement of the nuclei is observed. Neither any longitudinal split in the chromosomes nor any sharply distinct spireme is observed. The stage of spindle formation seems to be very rapid; this is also true regarding the arrangement of the chromosomes upon the equatorial plate. The chromosomes become fully organised and appear as globular bodies, when they take up their positions on the equatorial plate.

The homotypic spindles are found to lie either in the same plane or at right angles to each other. Obliquely oriented spindles are also not infrequent. A felted cytoplasmic zone is observed to lie between the spindles (Pl. XIII, Figs. 17 & 18). The movement of the chromosomes is generally regular, but sometimes a few laggards have been observed which ultimately reach the poles. On reaching the poles the chromosomes at first lie close to each other but very soon they open out and anastomosis are found between them. A nuclear membrane is observed and a nucleolus also makes its appearance at this stage. The spindle fibres disappear gradually and very soon four daughter nuclei are formed. All the nuclei increase simultaneously in size.

Cytokinesis and the formation of pollen grains: After the daughter nuclei have been organised, the pollen-mother-cell secretes a mucilaginous substance. Quadripartition takes place by furrowing. The furrows are first noticed at the periphery, equidistant to one another and gradually cut into the cytoplasm. They meet in the centre and separate the four microspores. The young microspores at first lie enclosed in a mucilaginous substance. Generally the arrangement of the spores is tetrahedral (Pl. XIII, Fig. 19). With the maturation of the spore, the mucilaginous substance dissolves out and spores are liberated in the microsporangium. Each spore has a thick wall of its own (Pl. XIII, Fig. 20).

The tapetal cells: Are large and columnar in shape and lie at right angles to the wall of the pollen sac. They are at first uninucleate and they remain so up to the open spireme stage of the pollen-mother-cell. Mitosis take place without the formation of a wall, giving rise to cells containing 2 or more nuclei. Vilcins and Abele (14) observed that in *P. Rhoeas* the tapetal cells ultimately become binucleate by mitotic division without the formation of any wall, "but in many between these nuclei can be seen some coherence, a kind of plasma bridge, or the nuclei may also be in connection between them forming a figure that looks like the amitotic division of a nucleus. There is reason to think that in these cases the nuclei flow together. There are also to be seen longish nuclei that are evidently formed by the junction of the two nuclei."

Discussion

Embryo-sac: Joshi (6) in the course of his investigations on the development of the megaspores of *Argemone mexicana* says, ". . . . it appears that there is only a single hypodermal archesporial cell which divides by a transverse wall to form a primary wall-cell and the megaspore-mother-cell. The wall-cell appears to divide once anticlinally and once or twice perclinally to form a partition of the wall 2 to 3 cells thick, which separates the sporogenous tissue from the epidermis of the nucellus." The accounts given by Vilcins and Abele (14) regarding the formation and division of the parietal cell in *Papaver Rhoeas* are also meagre. According to Vesque (13) *Papaver orientale* has no parietal cell. The present investigations, however, show that in *Argemone mexicana* a single archesporial cell becomes differentiated in the hypodermal layer of the nucellus. It very soon cuts off a parietal cell and then functions as the megaspore-mother-cell. Furthermore, from text figure 2 it is evident that the first division of the wall-cell is periclinal and not anticlinal as Joshi (6) has suggested.

The "T"-shaped tetrad which according to Joshi (6) is a characteristic feature of this plant, is of comparatively rare occurrence. The upper three megaspores of the linear tetrad degenerate and the chalazal one functions. In *Papaver Rhoeas* (14) also a linear tetrad is formed and the lowest one becomes the embryo-sac cell.

The embryo-sac is of the normal 8-nucleate type as has been observed by Joshi (6). Vilcins and Abele (14) also observed that in *Papaver Rhoeas* the mature embryo-sac was 8-nucleate.

One of the important features of the gametophyte of *Argemone mexicana* is the vigorous growth of the antipodals after fertilisation. The average dimension of an antipodal cell, when the endosperm nuclei form a lining layer around the nucellar cavity, is 154μ. Signs of degeneration of the antipodals are just noticeable at this stage. In *Papaver Rhoeas,* according to Vilcins and Abele (14), the antipodals are smaller than those of in other members of Papaveraceae.

Microsporogenesis: In *Argemone mexicana* the nucleolus of the pollen-mother-cell gives out bud-like processes during the early stages of meiosis. The chromaticity of the spireme threads appears to increase along with the distribution of these buds from the nucleolus. From the account stated above, it is clear that the nucleolus is the store-house of chromatin and it contributes chromatin to the developing spireme by budding. Such a behaviour of the nucleolus was described by Miss Digby (3) in *Primula kewensis* and other related hybrids and the same has also been observed by Mazumdar and Datta (8) in *Hibiscus mutabilis*. But Vilcins and Abele (14) have not mentioned any such behaviour of the nucleolus in *Papaver Rhoeas*.

Since the time of Flemming (Wilson 15) many cytologists regard the nucleolus as a reservoir of chromatin "destined to play some definite part in the later operations of the nucleus ('transportation hypothesis of Hæker') (Wilson 15, p. 95)". Our observations fully correspond to the above theory. The relevant literature on this point has already been thoroughly reviewed by Mazumdar and Datta (8).

The origin of spindle fibres is intra-nuclear. During the present investigation it appeared very probable that the reticulate "thread mass" or the "residual substance of the chromosomes" and the nuclear membrane help in the formation of the spindle fibres which later on are attached to the individual chromosomes. Similar observations were recorded by Latter (7) in *Malva sylvestris* and Datta (2) in *Cassia Tora*.

In this material, the side by side pairing of the threads almost throughout the length of the spireme and their close association with each other to form the double threads, the absence of second contraction, the segmentation of the pachytene thread into separate portions only, but not into loops, are sufficient evidence to justify the conclusion that the mode of chromosome pairing is parasynaptic. Vilcins and Abele (14) do not give any idea as to the mode of chromosome conjugation in *Papaver Rhoeas*.

As already mentioned in the text the middle portion of the cytoplasm between the interkinetic nuclei seems to have a greater affinity for retaining stains which is a characteristic feature observed in this plant. From the illustrations given by Vilcins and Abele (14) it appears that they did not observe such a differentiation of the cytoplasm in the pollen-mother-cell of *P: Rhoeas;* they, however, record that, "The nuclei instead of the spindle remain united to each other by a bridge of thick plasma . . . . The chromosomes after division (the second phase of the division) form the four nuclei of the tetrad, the strings of plasma between them can be observed for sometime. These plasma formations are observed not only between the daughter nuclei, but also between all four nuclei. Afterwards these formations disappear and the nuclei form the characteristic position of the tetrad." That differentiated zone in the cytoplasm as has been observed during the present investigation is not an artifact, can be proved by the fact that in a single anther loculus some mother cells in the early stages of the heterotypic and homotypic divisions show this characteristic appearance while they are not observed in more advance stages of the pollen-mother-cell.

The study of the chromosome numbers in the family Papaveraceae shows that there are two distinct polyploid series, such as 7–14–21–35 (common in the genus Papaver) and 11–22 (in *Papaver somniferum* and *P. satigerum)*. Variations in the haploid numbers such as n=6 and 8 are also recorded for *Platystemon californicus, Eschscholzia* with 4 sp., *Chelidonium majus* and *Corydalis pumila* and *C. cava.*

From the above it will be apparent that distinct polyploid series with aneuploid variations are present in the family Papaveraceae.*

Summary

1. The ovules of *Argemone mexicana* are typically anatropous and have two integuments.

2. The archesporial cell differentiates out in the hypodermis of the nucellus. It divides periclinally forming the wall cell and the megaspore mother cell.

3. A "normal type" of development of the female gametophyte has been observed and the mature embryo-sac is normal to the Angiosperm. The antipodal cells are very big and is a characteristic feature of the female gametophyte of *Papaveraceae.*

4. During early stages of meiosis in the Pollen-mother-cell the nucleolus buds out chromatic bodies and thereby contributes chromatic substances to the developing spireme. Vacuoles are present in the nucleolus during these stages.

5. The bivalent nature of the spireme becomes evident from the open spireme stage. The mode of conjugation follow the 'parasynaptic scheme'.

6. The origin of the heterotypic spindles is intra-nuclear.

7. A felted mass of cytoplasm forming the so called 'cytoplasmic bridge' is seen between the interkinetic nuclei after the 1st and 2nd divisions.

8. Cytokinesis takes place by furrowing and the mature pollen grains are uninucleate.

9. The haploid number of chromosomes for this species has been determined to be (n=14).

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* The chromosome numbers have been recorded from literature (11 & 12).

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Explanation of Plates

All the figures are sketched at table level with the aid of a Zeiss Camera lucida.

Plate XII

Combination of lenses: 1/12 mm. Zeiss Oil immersion (appt. 1.25) and ocular 15 × = × 1850 approximately for all figures except Fig. 8 which was drawn under 1/16 mm. Leitz Oil immersion and Zeiss appochromatic Ocular 15 × = × 2500 approximately.

Fig. 1. A resting nucleus in a Pollen-mother-cell. Deeply stained nucleolus has got a 'halo' round it. The reticulum has a granular appearance. The reticulum is slightly stained.

Fig. 2. Nucleolus showing formation of buds; one large and one small bud is seen attached to the nucleolus. Two small buds—one deeply stained is seen very close to it and the other in the peripheral region. Linin frame work is of granular appearance and merge on the side of the nucleolus.

Fig. 3. Nucleolus with a very small bud. Other buds of various sizes already detached; one seen towards the peripheral region. Nuclear reticulum also is faintly stained here.

Fig. 4. Leptonema stage.

Fig. 5. Destained nucleolus showing vacuoles.

Fig. 6. Synizesis. The tight-knot is composed of fine threads. Nucleolus with a bud not enclosed in the knot.

Fig. 7. Opening of the spireme from synizesis. Double nature of the spireme thread evident at places.

Fig. 8. Pachynema stage. Spireme showing distinct split throughout the length. The cut ends of the continuous spireme evident at some places.

Fig. 9. Diakinesis (early). Nucleolus is less chromatic. Each segment of the broken spireme showing parallel association. Beaded granules are clearly seen side by side and embedded in a less attainable matrix.

Fig. 10. A later stage of Diakinesis showing further condensation of the bivalents. Some bivalent chromosomes with the discarded portions of linin attached by their sides can be seen.

Fig. 11. Late Diakinesis.

Fig. 12. Spindle formation. Spindle fibres are attached to the chromosomes and are seen crossing and inter-crossing one another.

Plate XIII

Fig. 13. Heterotypic metaphase plate showing 14 haploid chromosomes.

Combination of lenses: 1/12 mm. Zeiss Oil immersion (appt. 1.25) and Ocular 10× = × 1150 approximately.

Fig. 14. Heterotypic anaphase (lateral view). Each univalent is seen to be attached terminally by a group of spindle fibres.

Fig. 15. Late telophase. Nuclear wall already established but nucleolus cannot be traced uptil now. Individual chromosomes are seen attached to one another by fine threads. Central portion of the cytoplasm between two nuclei forming a thick cytoplasmic bridge.

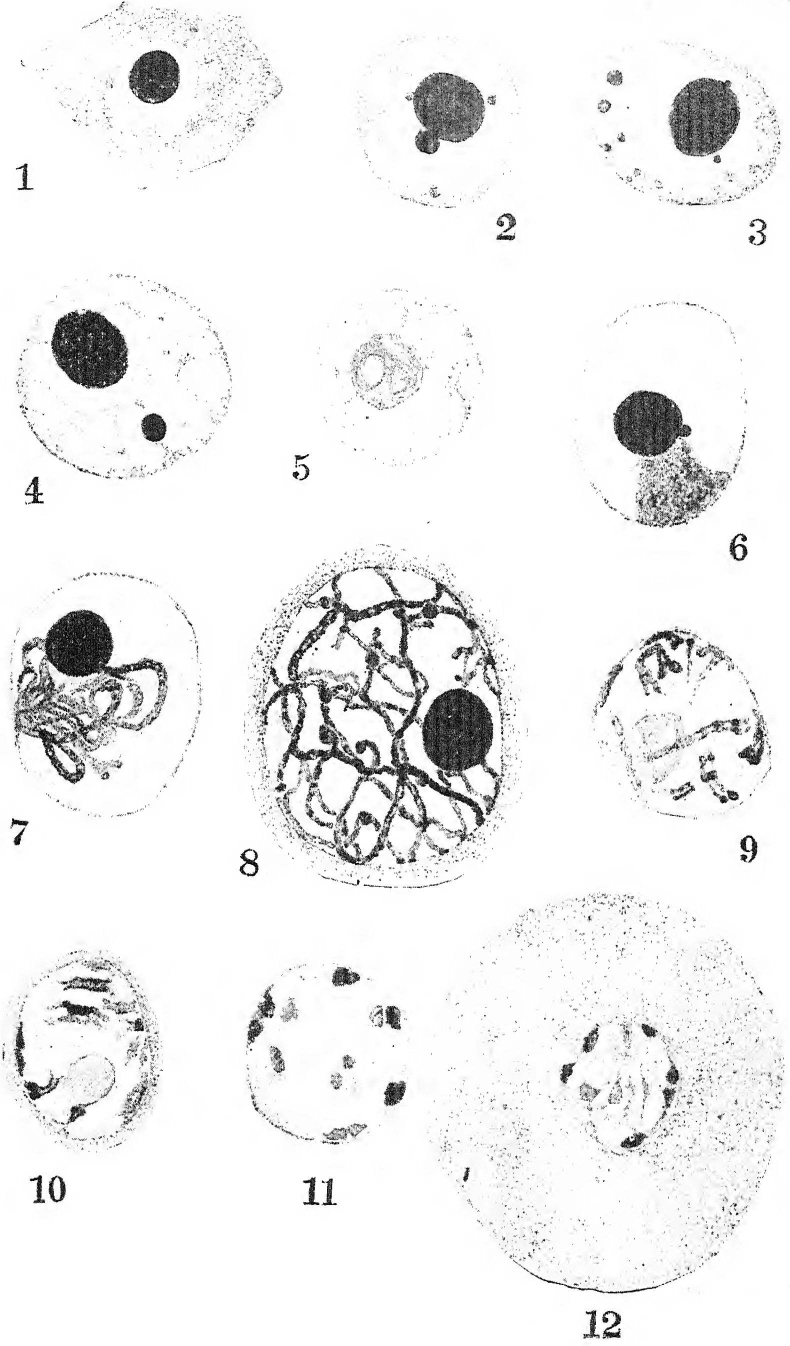
Fig. 16. Interkinesis. The cytoplasmic bridge very distinct and conspicuous.

Fig. 17. Homotypic metaphase. Two spindles in the same plane separated by the cytoplasmic bridge.

Fig. 18. Homotypic telophase. 14 univalent chromosomes are seen in the polar view. Cytoplasmic bridge still conspicuous.

Fig. 19. Tetrad of microspores. The microspores are completely separated from one another by cytokinesis. The nuclei of the microspores are in resting condition. All the spores are enclosed in a mucilaginous pellicle.

Fig. 20. A mature uninucleate pollen grain with a thick wall.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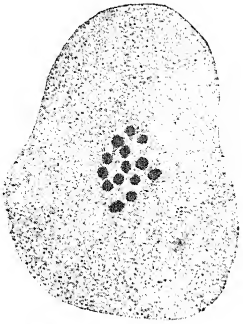
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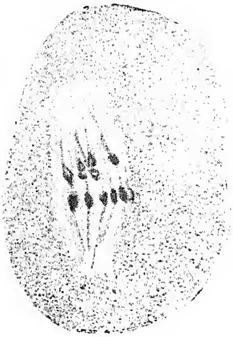
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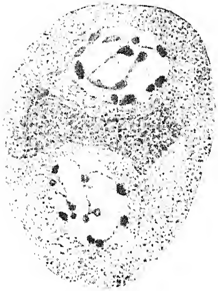
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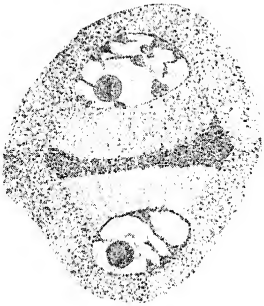
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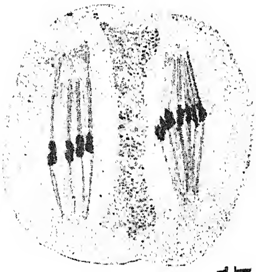
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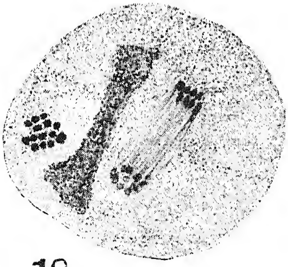
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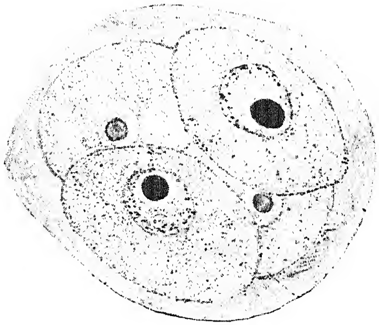
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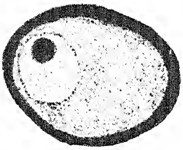
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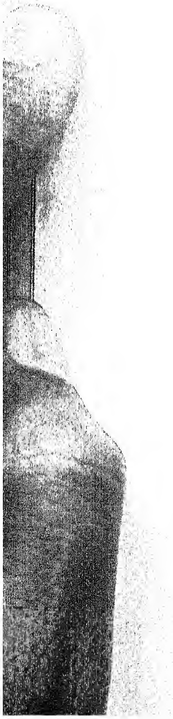

THE ECONOMIC IMPORTANCE OF CHANGES IN PLANT COVER *

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Communicated by H. Chaudhuri

Recent activities in the U. S. A. have emphasised the need for careful retention of plant cover on all agricultural and waste land which is not actually ploughed. The farming community there has in the last two centuries exhausted a series of land frontiers. to each of which a fresh advance was made westwards as the older eastern settlements became fully developed; and it is now a common saying that the only "frontier" left is the soil beneath the farmers' feet. In other words, no further expansion is possible geographically, and it now remains to conserve and develop to the utmost the land resources as they now exist. That earlier farming and land use methods have failed to do this is patent from many projects now receiving government support, e.g., the shelterbelt tree planting to anchor wind-blown soils in the Middle West, large-scale attempts to replace prairie turf on land which should never have been ploughed up, the general alarm over the rate at which vast and costly reservoirs are silting up, and the many attempts to survey and assess land values in order to withdraw from cultivation land which ought never to have been cleared of its primeval forest cover.

In India it is not generally appreciated how very similar are many of the land problems of these two vast countries. The older civilisation of India has remained stationary for centuries and has continued to thrive without any spectacular migrations to fresh frontiers, but there the difference ends. In India pressure of rapidly increasing population neutralises laudable efforts to raise the standard of living and of nutrition, and the drain of centuries of cultivation has exhausted the soil more slowly but not less surely than in America. The fresh land frontiers made available by our great irrigation projects are more or less colonised and the Indian population, like the American, is face to face with the fact that only through more efficient use of the land's resources of soil and water can they remain above starvation level. The immense areas in India now under perennial canal irrigation are not by any means sure of their winter water, and the progressive deterioration in the condition of the hill catchment areas exaggerates the severity of the drought periods which endanger their prosperity. Even industrial activities are affected by the same factors of alternating flood and drought, economically because of the resulting poverty of the zamindar purchaser, and technically because of their dependence upon water supplies for manufacturing processes and for hydro-electric power.

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*This paper was presented to the Botanical Section of the Indian Science Congress, 1937.

To appreciate fully the value of plant cover in reducing and controlling the run-off, it is necessary to visualise the whole process of seepage by which surface waters find their way into the deeper strata of soil and rock to feed the underground reservoirs which maintain our perennial springs. The ideal catchment area is one completely clothed in either forest or grass-land, where the natural vegetation has been preserved undisturbed and has been allowed to build up a deep soil profile. The gradations from the living plant cover on top down through the humus layer to the mineral subsoil below are blended into one physical unit, and this is nature's own provision for efficient disposal of rainfall. The porosity and capacity to absorb surface moisture through any complete natural soil profile is truly amazing.

No matter how heavy the rainfall, a very large part of it is delayed by the surface mat of vegetation and passed downwards through the porous layers to the rock cavities and underground storage chambers which are the chief support of perennial springs. Anything which interferes with the porosity of the soil or with the healthy condition of the vegetation cover must inevitably affect the percentage of rainfall which finds its way underground. Of the various factors affecting the plant cover, such as clearing of grass-land or forest by burning or felling, ploughing, grazing, etc., grazing is probably the most widespread and most insidious. Constant heavy grazing by underfed animals, such as occurs on village common lands throughout India, leads inevitably to the thinning out of the vegetation and to compacting the soil into a solid mass, so that the reduced cover is less capable of checking surface run-off and the altered soil profile below is less capable of absorbing it.

America has produced some striking figures to show the value of her water resources and the importance of water conservation. In India we can produce similar data. In the 150 square mile catchment of the Uhl river which supplies the Punjab hydro-electric plant at Jogindernagar, the government income from all sources of revenue for land and grazing amounts to Rs. -/-/3 (one farthing) per acre but the money invested in the project amounts to Rs. 730 (or £5/-/6) per acre of the catchment area, though nothing has so far been spent upon the catchment area itself, and the continuity of a sufficient water supply has been more or less taken for granted. The continued efficiency of such areas in producing sustained and sufficient water flow is therefore of paramount importance. The object of this paper is to show how this can be achieved through the maintenance of the plant cover as near as possible to its normal condition.

Two examples will be discussed which, it is hoped, will emphasise the need for this, one in the East Punjab and one in the West, because their climatic conditions vary considerably. The Eastern Punjab hills have a fairly heavy monsoon and considerably more rain at intervals during the rest of the year, totalling 70 to 120 inches. The vegetation is in keeping with this, and ungrazed land produces a lush crop of herbaceous weeds and grass in the monsoon, persisting to some extent throughout the rest of the year, and giving a very efficient natural plant cover. If this plant cover is destroyed by grazing or fire, the damage done in sheet-washing by frequent heavy rainstorms is very serious indeed. In the drier western half the total rainfall is much less (10 to 30 inches), and one might expect the erosion to be less serious in consequence, but this is not so. Infrequent but heavy storms here fall on a land whose natural vegetation cover is very thin and sparse, so that the erosion loss from each big storm is serious, and the long intervals of drought and low humidity limit the plant life severely, both in the number of species and in its efficiency in building up a porous soil. On a sandy soil grazing damage shows chiefly in spoiling the stability of the top-soil, while clays become easily puddled into a brick-hard and unaerated mass in which plant roots can no longer persist.

The Eastern Punjab example is the catchment area of the Uhl which supplies water-power for the 140,000 kilowatt hydro-electric plant at Jogindernagar, and on which the prosperity of the Punjab's numerous industrial activities now largely depends. The hills range from 6,000 to 16,000 feet in altitude, and the country is exceedingly rugged and steep. It falls naturally into the following four zones of roughly equal area:—

(i) valley bottom cultivation and common grazing upto about 9,000 feet, along very steep banks of glacial moraine exposed by a typical V-shaped erosion valley cut by the river through the older and wider U-shaped glacial valley. This zone comprises 21,000 acres, 55% of which is eroding seriously.

(ii) a middle forest belt, 9,000 to 11,000 feet, of more or less continuous oak (*Quercus semecarpifolia*) and coniferous trees interspersed with grassy glades; this comprises 20,000 acres, 15% of which is in an unsatisfactory condition for water catchment.

(iii) an alpine pasture belt, 11,000 to 13,000 feet, comprising 25,000 acres, 32% of which is eroding to some extent.

(iv) a snow belt above 13,000 feet consisting mostly of bare rock and cliffs, stony screes, some birch and dwarf rhododendron where these can find soil, and a good deal of permanent snowbeds and glaciers.

The total run-off at Brot weir varies between a maximum of 4,000 to 5,000 cusecs (cubic feet per second) in summer when heavy monsoon rain combines with the steady melting of snow-beds and glaciers to cause floods, and a minimum of about 100 cusecs. The engineers' requirement is for a steady 300 to 400 cusecs, so that the chief problem is the decreased flow in winter when the power-load is heaviest. The stream was carefully gauged before the project was started, and it appears that even in the decade since this was first done the winter flow has deteriorated, falling to a fresh record nadir of 80 cusecs for some days in January 1935 and February 1936. The nadir flow is due presumably to frost in the higher hills causing a physiological drought everywhere above the 9,000 foot contour, combined with progressive desiccation and destruction of plant cover which previously conserved the subsoil drainage and cold weather spring flow in the lower valley. The causes of deterioration in this catchment's efficiency are not far to seek. A detailed survey of erosion conditions carried out in May and June 1936 by Forest Ranger Puran Singh and the writer leads to the following conclusions, dealing with each altitudinal belt in turn, and giving suggested remedies.

(i) *Valley Bottom.*

(a) Cultivation Methods. Primitive and ineffective terracing of field cultivation on very steep clopes. Increase in acreage under potatoes, which are a particularly bad crop for causing erosion. Shifting cultivation on unterraced land some distance from villages leads to abandonment after a few years' cultivation, after which it is heavily grazed and eventually retrogrades to stony scree. Landslips are formed by throwing the concentrated drainage of groups of fields into channels which erode the loose boulder beds of the glacial moraine. Much of the cultivation farthest from the villages depends upon manuring by sheep and goats and the migratory flocks thus have to squat in these areas and browse in their immediate neighbourhood. Blocks containing the steepest fields should be taken out of cultivation and reforested.

(b) Grazing. Heavy grazing by village herds on all waste land adjoining villages leads to sheet-washing of the steep and poorly clad slopes, leading eventually to gullying and the formation of stony scree. Improvement lies in the encouragement of grass-cutting and stall-feeding in preference to grazing, and in the elimination of useless live-stock.

(ii) *The Forest Belt.*

The forests are on the whole in much better condition for water storage than the lower land, but the cover is deteriorating to some extent through persistent destruction of young oak trees by the migratory flocks. This leads to a gradual opening of the forest canopy as the old trees become over-mature and die with nothing to replace them. Prevention of this lies in rotational closure of the oak forests for a period long enough to allow browsed shoots to produce fresh leaders and grow beyond the reach of browsers.

(iii) *The Alpine Pasture Belt.*

The Gaddi shepherds en route from winter grounds in Kangra and the Siwaliks to summer pastures in the high Inner Himalayas of Chamba, Bara Banghal, and Lahoul pass through in spring and autumn. Many fine areas remain unused and are knee-deep in herbs in autumn, but intense grazing occurs along the main alpine routes, and heavy damage occurs where flocks are pushed too early up to the alpine belt when the turf is still dead and spongy with snow-melt. Prevention lies in better control of the Gaddies' movements and the replacement of goats with sheep, which are much less destructive. It is not feasible to change the Gaddies' migratory habits, nor is it desirable to discourage them, for it is only through grazing that the fine natural resources of the alpine pastures can be harvested.

(iv) *The Snow Belt.*

As this area carries little vegetation and is more or less frozen during the winter months, it does not have much influence upon the problem. Little control of the run-off is possible except where a patchwork of forest and glades, so strongly recommended by the International Commission of Snow as an efficient catchment cover, might possibly be developed. This could be done by excluding the migrant herds from prescribed areas and the cover of willows, birch and dwarf rhododendron could be improved by afforestation below the upper limit of tree growth, which is for all practical purposes about 12,000 feet.

The Western Punjab example is the Pabbi Hills, situated in Gujrat district and running into the plains on the east or left bank of the Jhelum river. This is a low range of hills rising to scarcely 600 feet above the adjoining river bed, but consisting of soft and friable strata of Siwalik sand-rock and scarcely compacted conglomerate and pebble beds, the most easily eroded and least fertile being a deep bed of red shale which crops out frequently in the steep nala banks. The rainfall averages about 14″ but occurs as a few erratic but exceedingly violent downpours during the summer, with very long intervals of drought. A landscape of deeply carved torrent beds which drain the small intervening plateaux to a great depth combines with the scanty rainfall to render the vegetation thin and precarious even when fully protected, and exceedingly vulnerable to any form of grazing, browsing, or clearance of vegetation. There are three easily differentiated conditions of plant cover:—

(i) Some 3,500 acres in the middle of the range have been for some years under constructive counter-erosion treatment for afforestation with the Mexican mesquite (*Prosopis glandulosa*) and the damming of torrent channels with stone and earth bunds.

(ii) The rest of the range classed as reserved forest has been under a regime of passive protection by closure to grazing, but actually owing to rights of way and lack of protective staff, a good deal of grazing and browsing has taken place.

(iii) A portion of the hills to the south-west has been omitted from the reserve and has been used as a grazing ground by local Gujar villages. Although this is actually less steep than the rest of the range and the original conditions were otherwise comparable, the thorn scrub has now been almost exterminated and the area is a waste of shifting sand with the fringes of the broad sandy torrents marked by lopped *dhak* trees (*Butea frondosa*).

The relative value of these three types of cover is well shown in the figures of run-off which have been collected, partly by the Irrigation Branch from their torrent syphons by which the flood waters from these Pabbi torrents have to be led under the Upper Jhelum Canal bed, and partly from observations in the afforestation area.

(i) The afforested area shows a maximum flood intensity of less than 100 cusecs per square mile, and the valleys of the treated streams below the reserved forest boundary have been repopulated and are now cultivated up to the very margin of the narrow stream channel. Flood water takes about 6 to 10 times as long to pass down as in the class (ii) torrents.

(ii) Torrents from the passively protected forest reserve attain a maximum flood intensity of about 600 cusecs per square mile. The sudden and dangerous crest of the initial wave spreads out over a considerable area of sandy bed below the forest boundary, rendering cultivation unsafe within several hundred yards of the stream's route, and threatening the safety of the canal syphons.

(iii) In that part of the Pabbi which is entirely open to grazing and no protection has been attempted, constant heavy grazing has so depleted the plant cover that although the slopes are gentler than elsewhere in the range, the average maximum flood intensity reaches the alarming figure of 1,600 cusecs per square mile. This exposes the rather antiquated brick-arch syphons to a serious danger of bursting, and to prevent this happening the canal has to be run full during the monsoon. The violent and heavy discharge of these grazed areas also causes prolonged flooding in the adjoining flat country where the natural drainage channels are unable to cope with such quantities, and this in turn exaggerates the already pressing problem of the rising water table in the lower reaches of the Upper Jhelum Canal colony.

Admitted that the danger to this canal is a unique phase of torrent action, the comparative figures of run-off for these three types of vegetative cover on the same terrain give striking statistical proof of what students of plant life have long known, namely that what far exceeds in importance all other factors such as climate, slope, and soil, in the control of run-off is the condition of the plant cover.

Summary

Similarity of land use problems in India and U. S. A. is stated and object lessons already learnt in the States applied to Indian conditions, e.g., more rational use of non-plough land to conserve grazing resources and water supplies. The importance of managing hill catchment areas primarily for their value as catchments—e.g., the Uhl river supplies the Punjab Hydro-Electric plant from a catchment of 150 square miles the government revenue from which is Rs. -/-/3 per acre as compared with an investment amounting to Rs. 700 per acre on electric plant, the security of the investment being entirely dependent upon the behaviour of this stream.

Value of plant cover as a major factor controlling stream flow is emphasised by describing the process by which seepage of surface water through soil layers builds up underground reservoirs which maintain perennial springs. Porosity of soil and its capacity to allow seepage depend upon condition of soil profile. Maximum seepage is provided by profile maintained by ecological climax vegetation. Whatever reduces protective value of plant cover interferes directly with the porosity of the soil. In India the chief cause is heavy and uncontrolled grazing.

Data are quoted for 3 grades of plant cover density in the Pabbi Hills (Punjab) showing the maximum flood intensity which each gives rise to:—(i) land treated by afforestation and active counter-erosion work gives less than 100 cusecs per square mile maximum flood and renders cultivation possible up to the edge of the small stream channel; (ii) land protected by partial closure to grazing gives 600-700 cusecs per square mile with correspondingly rapid and dangerous flood peaks, rendering cultivation impossible inside a wide flood channel; (iii) unprotected land constantly overgrazed gives a maximum flood intensity of 1,600 cusecs per square mile.

Explanation of Plates

PLATE XIV

The Uhl valley is the source of water power for the Punjab's big hydro-electric plant. The Catchment Area consists of partially terraced cultivation along the valley bottom and above this is forest and alpine pasture. The deodar forest seen here belongs to Mandi State.

PLATE XV

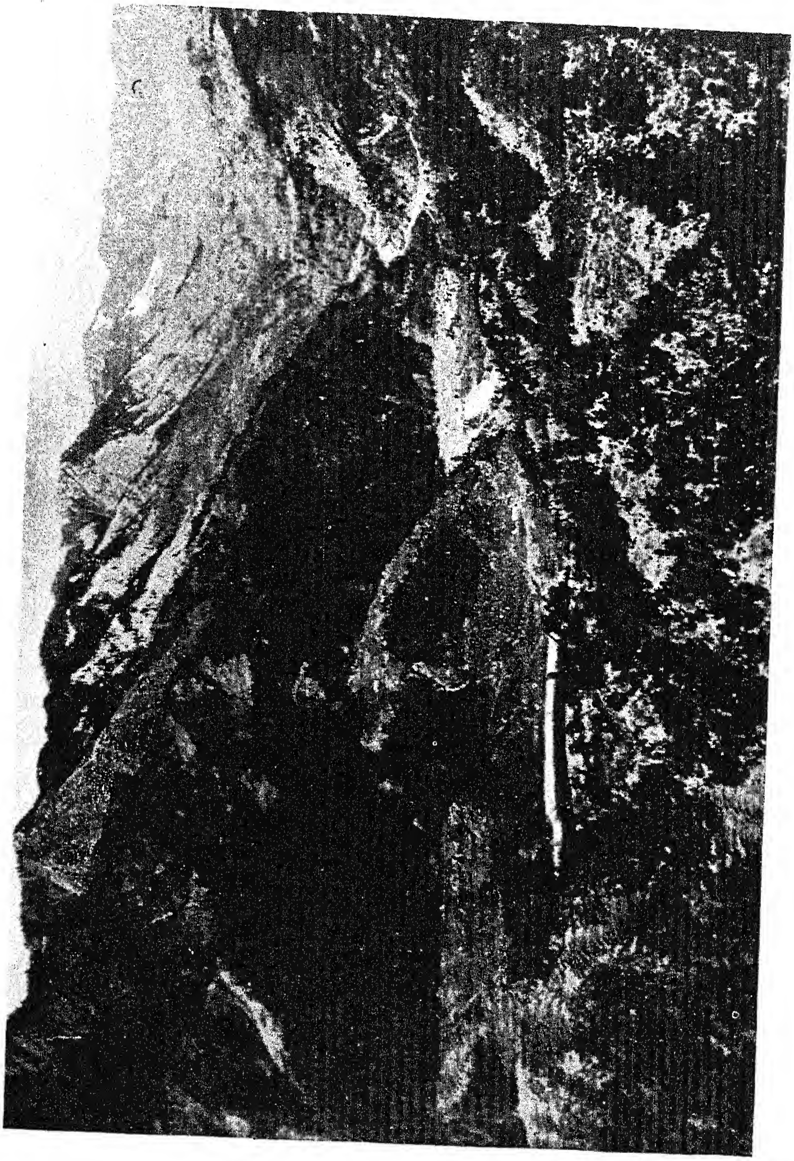
Broad-leaf forest, mostly *Quercus*, on a very steep slope of 65°, has been felled and uprooted to make way for shifting cultivation, the ground remaining quite unterraced. The soil loss by erosion from such exposed slopes is probably about 200 tons per acre per annum and after a few years nothing but a screen of stones remains. Uhl Catchment Area.

PLATE XVI

The foreground shows primitive attempts at terracing for cultivation on very steep slopes. The right background shows huge unstable slips resulting from earlier cultivation of the same type. Uhl Catchment Area.

PLATE XVII

A landslip which started 50 years ago from the uncontrolled drainage of a block of fields. Its head is now 1,800 feet above the river level whence this photo is taken and it continues to expand yearly. Uhl Catchment Area.



R. M. GORRIE—*IMPORTANCE OF PLANT COVER*

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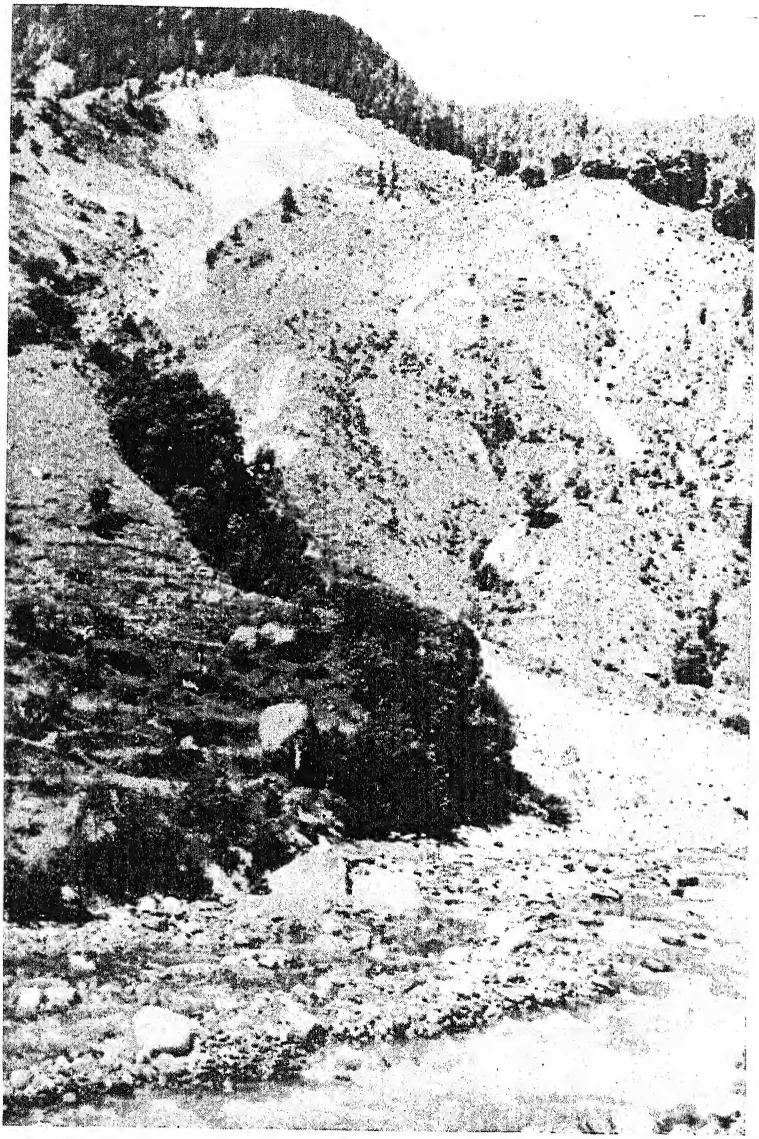

R. M. GORRIE — *IMPORTANCE OF PLANT COVER*

A NOTE ON THE VARIATIONS IN LEAF-FORM AND ASCIDIUM FORMATION IN *TABERNÆMONTANA CORONARIA* R. Br.

BY

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Received for publication on 14th January, 1937

In the year 1932 some cup-shaped leaves were noticed by the author on a plant of *Tabernæmontana coronaria* growing in his compound. Curiosity led to subsequent observations of several plants in the locality which revealed the presence of such ascidium formation as well as many variations in the leaf-form. Such variations were found to be more abundant in plants with luxuriant growth than in plants of poor growth. Material was collected from these plants and preserved for future work. Occurrence of ascidia and the other variations in leaf-form have been observed in these plants in subsequent years as a common feature.

Variations in leaf-form and the formation of ascidia of the entire leaf have been observed in many plants among Angiosperms, such as *Gastria,*[6] *Agave,*[6] *Staphylea,*[6] *Euphorbia,*[6] *Nicotiana,*[2] Bamboo and *Ginkgo.*[4] In addition to these important cases, there are good many instances of such variations on record.[3] So far as these records go, no such case has been described in *Tabernæmontana coronaria.* Further, these variations can be observed to form a graded series from a simple opposite leaf to a terminal solitary leaf which, invariably exhibits some peculiarity like forking, adnation at the base and ascidium formation. On account of these interesting points, some of such abnormalities have been recorded with the necessary details.

Variations in leaf-form fall under the following classes:—

1. *Forking from the tip of the leaf:*—Ordinarily the leaves of *Tabernæmontana* are simple, petiolate, opposite-discussate and symmetrical about the midrib. In cases of forking, the midrib also takes part, thus giving rise to two asymmetrical halves having a common basal part of the leaf. (Fig. 1, H, I, J.) The petiole bifurcates from the middle of the blade onwards and ends in two tips. The vascular anatomy of the petiole is also interesting in differing from that of the normal petiole (Fig. 2, D & E). As seen in a transverse section, the petiole is traversed by two vascular strands of semicircular outline. They incline towards each other, the xylem of each strand having internal and external phloem.

2. *Adnation of the petiole to the axis:*—The adnation is common and it is so perfect in some cases that it is difficult to make out this feature on a casual observation. But the axillary bud that develops at the free point is suggestive of the adnation. For all outward appearances, it looks as though the bud is situated on the adaxial side of the petiole midway between the axis and the insertion of the blade.

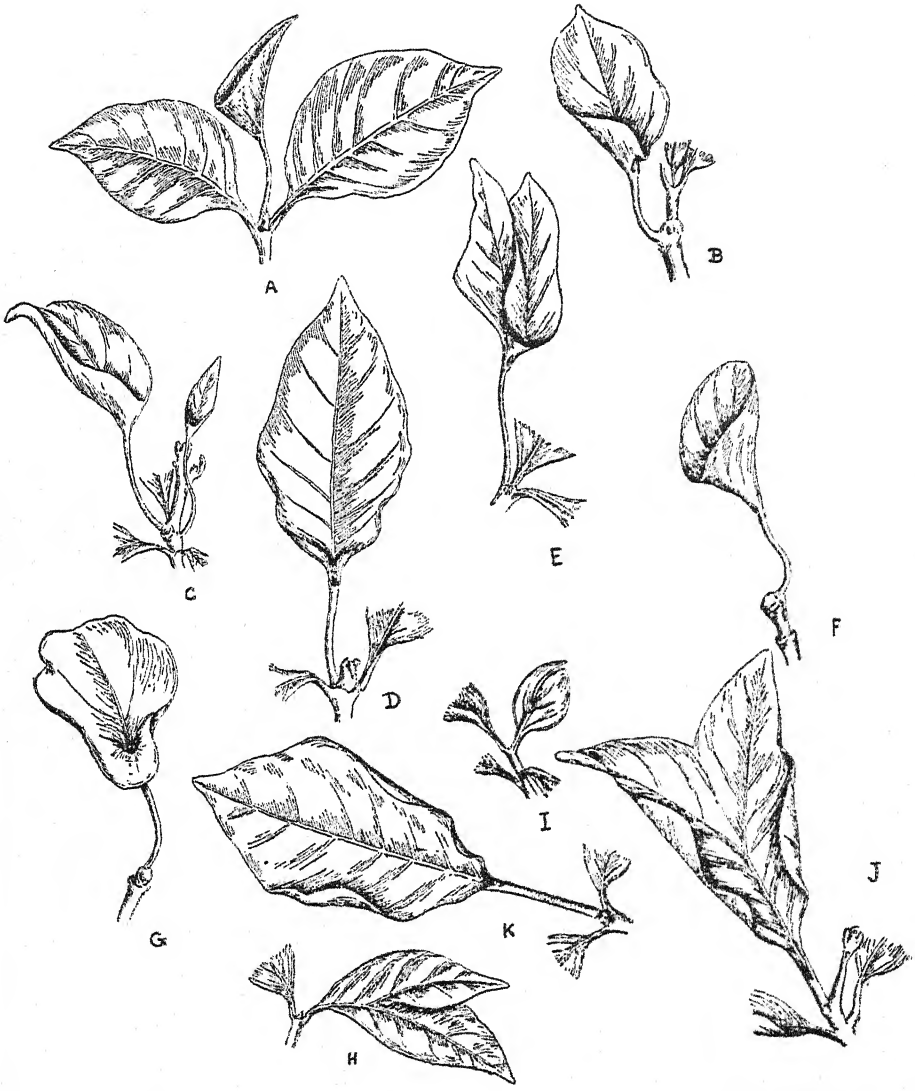

Fig. 1.—*Tabernaemontana coronaria* R. Br. A to J have been drawn to the actual size. A to G are the various stages in the formation of the ascidium. H, I and J are stages in the forking of the leaf. K is the terminal leaf.

3. *Single terminal leaf:*—This is of very common occurrence and the terminal leaf is much bigger than the normal leaves of the lower nodes. They occasionally exhibit adnation also and, when this is not found, the petiole remains perfectly cylindrical and of uniform thickness throughout its length. In fig. 1, K, one of the three leaves of a whorl is very much bigger than the other two suppressed ones and presents the appearance of a terminal leaf. The false appearance of it is clear at the outset.

4. *Formation of ascidium:*—The transition from the terminal single leaf to the ascidium that invariably terminates the axis is very gradual. Terminal leaf with a slight basal pouch forms the first stage (Fig. 1, D). This pouch gradually develops into a pocket (Fig. 1, B & E) which by further growth and approximation of the edges becomes a funnel shaped ascidium (Fig. 1, A, C, F, G). It is clearly seen that the adaxial side of the leaf becomes the inner surface of the funnel, a condition quite the opposite of what is found in the case of *Ficus Krishna* or *Brassica oleracea*[6] but similar to that of *Pelargonium zonale*[6] or *Nicotiana tabacum*[2]. The anatomy of the wall of the ascidium remains like that of the foliage leaf throughout except at the base of the funnel, where the tissue ruptures ultimately leading to the formation of an aperture (Fig. 1, B, D, E). This aperture is of later formation, the young ascidium being devoid of it. The edges bounding the aperture is well protected by a layer of cork-cambium and its products. In some instances, proliferation of the tissue precedes the formation of the aperture.

The stalk of the funnel is cylindrical and its anatomy is interesting as in the case of the terminal single leaf. A transverse section of it shows the central core of pith surrounded by a circular band of xylem. The xylem is surrounded by a ring of phloem. In addition to this extra-xylary phloem ring, there is an intra-xylary phloem ring forming the inner boundary of the xylem band (Fig. 2, B). Thus the structure of the stalk of the ascidium differs from that of both the stem and the petiole of the normal foliage leaf, but resembles that of the petiole of the terminal leaf. It differs from that of the stem in not possessing the zonal cambium and from that of the normal petiole in not possessing an arch shaped xylem forming a single bicollateral strand (Fig. 2, C & D). The gross anatomy of the stalk of the ascidium on the whole, resembles that of the young stem[5].

Further variations of this ascidium, as shown in Figure 1, E & G, are also interesting, in pointing towards the formation of a double ascidium.

Discussion

The above described variations and ascidium formation constitute some of the most interesting teratological phenomena in the plant kingdom and are very difficult of interpretation. An attempt has been made here to bring out the details of these peculiarities without discussing their significance. It is made with the hope that more and more knowledge of such variations in plants and their anatomical details will positively take us a long way in finding out their true morphological significance than a mere theoretical consideration.

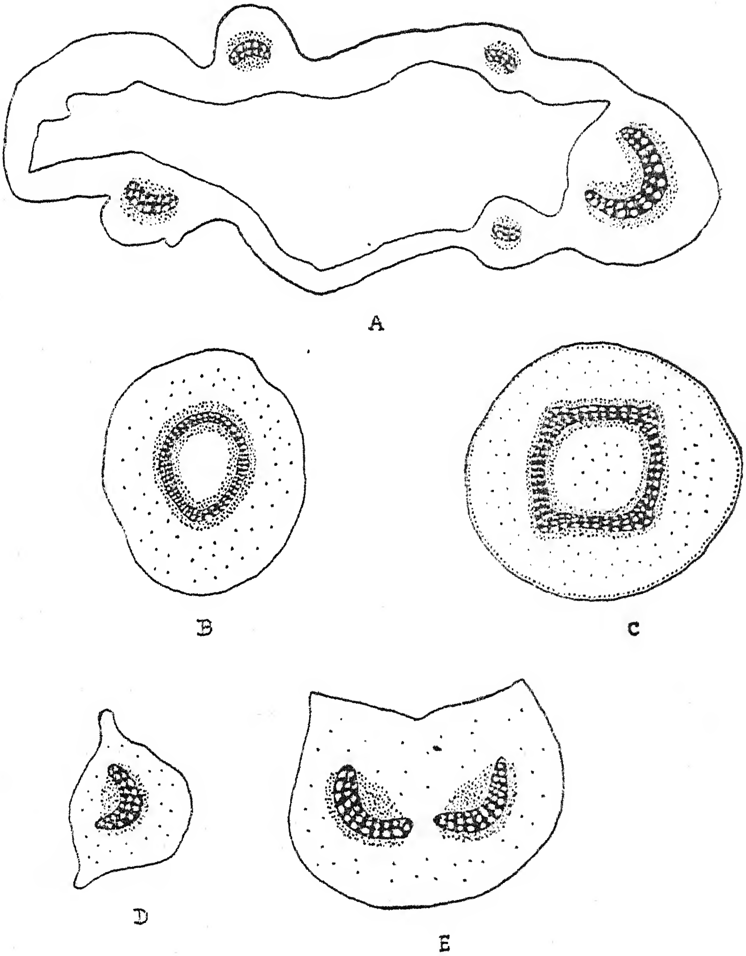

Fig. 2.—*Tabernaemontana coronaria* R. Br. A to E are drawn with the help of camera lucida magnified 25 times. Phloem dotted and xylem black areas. A. Transverse section of an ascidium as in Fig. 1. A, just above the aperture. × 25. B. Transverse section of the stalk of the ascidium. × 25. C. Transverse section of the young stem, × 25. D. Transverse section of the normal petiole. × 25 E. Transverse section of the petiole of the forked terminal leaf as in Fig. 1. J.

However, the ascidium formation on the lines described above and as evidenced by Fig 1, A to G, is very suggestive indeed; but to believe an ordinary, simple, bifacial, dorsiventral leaf to suddenly become a terminal funnel-shaped one is rather difficult, specially in the light of our knowledge of the leaf and its morphology[1]. It is also possible to consider the terminal leaves and the terminal ascidia as representing not one leaf whose margins have become congenitally fused, but two leaves, i.e., opposite leaves of a node. This idea gets additional support from the anatomy of the same stalk, whose xylem ring is really made up of two semi-circular xylem strands of the two leaves concerned.

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Summary

1. Some variations in leaf-form of *Tabernœmontana coronaria* R.Br. have been described.

2. The more interesting form of variation, e.g., ascidium formation has been studied in the light of previous recorded cases.

3. The anatomy of the stalk of the ascidium has been found to lend some support in explaining the morphology of the ascidium.

A NEW NITELLA FROM RAJSHAHI, BENGAL

BY

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Received for publication on 14th January, 1937

The present paper deals with the description of a new species of *Nitella,* which has been collected from the district of Rajshahi, Bengal, in the month of January, 1936. It is a heterodoctylous *Nitella.* On careful examination it appeared to the author to be a new species and for the purpose of confirmation, a few specimens were sent to Mr. G. O. Allen, who was for a long time associated with the late Mr. Groves in the study of Charophytes and is at present in touch with the specimens of the British Museum and the Kew Herbarium. Mr. Allen has also confirmed it to be a new species. The author wishes to express his sincere thanks to him.

Description:

Nitella tuberculata sp. nov.

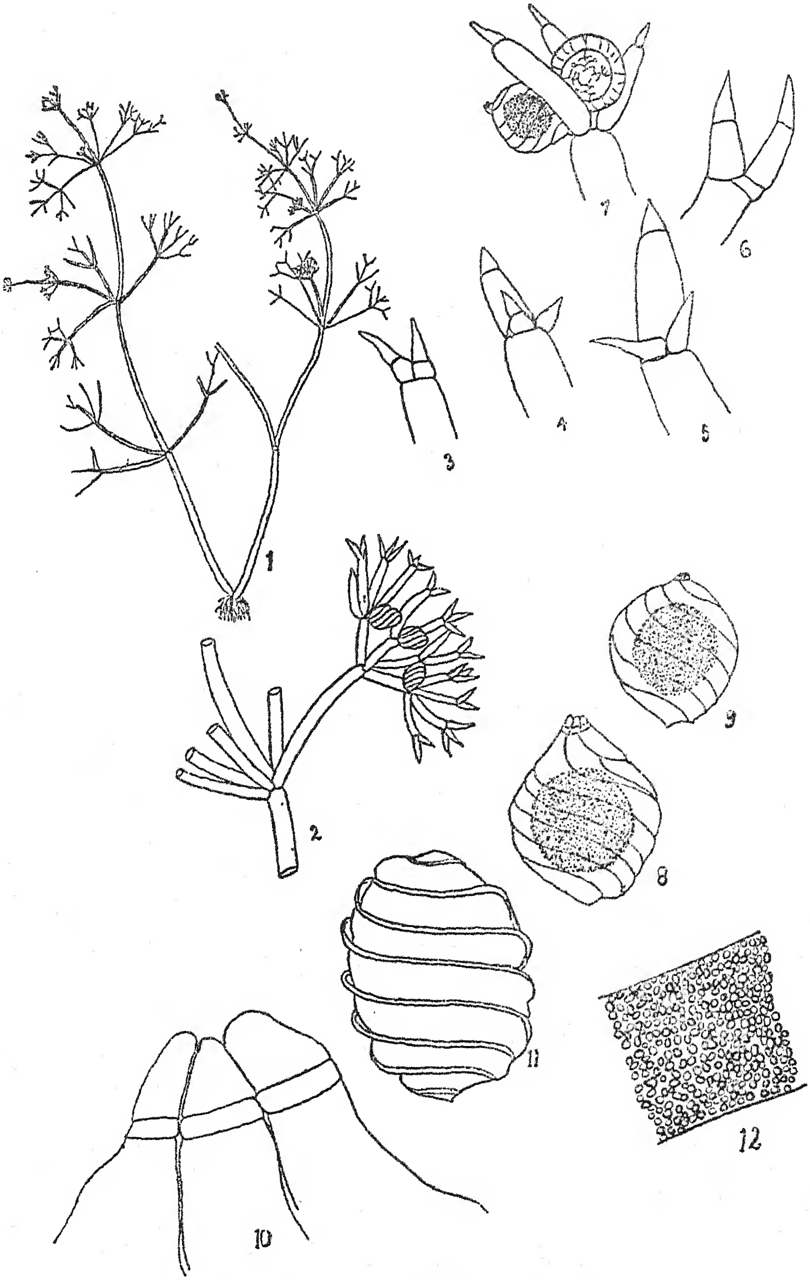
Nitella homoeoclema, heterodactyla, flabellata, gymnocephala, monoecia.

Monoecious; stem rather slender, diameter at the lower internodes 450-525μ; not incrusted.

Branchlets: sterile whorls—branchlets 4-6 in a whorl; longer than the fertile ones; 1¾ to 2 cm. in length; primary rays—1 to 1¼ cm. long; secondary rays—4-5; tertiary rays—2-3; rarely one of them is again furcate into 2 quaternary rays. At the first node of these branchlets occasionally a capitula bearing fruiting organs may be found. Fertile whorls—branchlets usually 5, sometimes 6; 2-3 times furcate. Primary rays more than half of the entire branchlet; secondary rays 5-6; tertiary rays 3-4; quaternary rays 2-3.

Dactyls: unequal, usually 2-celled; lower cell tapering and upper cell acute or acuminate. Occasionally here and there one-celled dactyls are found. Rarely three-celled dactyls may be seen.

Fructifications are found in lax capitula and also in the furcations of the branchlets. They are not found in the first furcation of the branchlets. Antheridia and oogonia are rarely found together. Antheridia are usually found at the terminal furcations of the very young branchlets. Sometimes at these places antheridia and oogonia



Figs.—12. *Nitella tuberculata* sp. nov.

Fig. 1.—A plant, (about natural size). Fig. 2.—Branchlets of a fertile whorl. × 5. Figs. 3-6.—Dactyls. × 20. Fig. 7.—Terminal node of a branchlet showing antheridium and oogonium. × 20. Figs. 8 & 9.—Oogonia. × 20. Fig. 10.—Coronula of the oogonium. × 230. Fig. 11.—Oospore. × 55. Fig. 12.—Oospore membrane showing tuberculate decorations. × 230.

ADDENDUM

to Mr. B. C. Kundu's paper, "A new Nitella from Rajshahi, Bengal"

(Journal of the Indian Botanical Society, Volume XVI, No. 4, pp. 223-226, 1937)

Please add the following matter on p. 225 after line 6 from the top:—

Monoecia ; caulis aliquanto tenuis, ad internodia inferiora 450-525μ diametro ; non incrustata.

Ramuli ; verticilli steriles—ramuli 4-6 verticillo, longiores quam fertiles ; $1\frac{3}{4}$—2 cm. longi: radii primarii 1-$1\frac{1}{4}$ cm. longi; radii secundarii 4-5 ; radii tertiarii 2-3; quorum 1 raro in radiis 2 quaterniis iterum furcatus est. Eorum ramulorum ad nodum primum aliquando capitulum gametangia tenentum apparet. Verticilli fertiles—ramuli plerumque 5, aliquando 6; 2-3 furcati. Radii primarii $\frac{1}{2}$ quam ramuli longiores, radii secundarii 5-6; radii tertiarii 3-4, radii quaternarii 2-3.

Dactyli inequales, plerumque bicellulati; cellula inferiora attenuata et cellula superiora acuta vel acuminatis. Aliquando hac atque illac dactyli unicellulati et raro dactyli tricellulati reperti sunt.

Gametangia in lax capitula et in ramulorum furcationibus reperta sunt. In ramulorum furcatione prima non reperta sunt. Antheridia et oogonia rare simul. Antheridia ad ramulorum novellisimorum furcationes terminales plerumque reperta sunt. In his locis antheridia et oogonia simul aliquando reperta sunt. Oogonia plerumque ad furcationes secundes. Antheridia - 195-210μ diametro. Oogonia—570-615μ longa (coronula exclusa) et 450-480μ lata. Coronula persistens 35-42μ lata. Cellulæ spirales 7-8 convolutas exhibentes. Oospora flava, 7-8 demissa iuga exhibens, 345μ longa et 300μ lata. Membrana tuberculata.

are found together. Oogonia are usually found at the second furcations of the branchlets. Antheridia—195-210μ in diameter. Oogonia—570-615μ long (excluding coronula) and 450-480μ broad. Coronula—35-42μ high. Spiral cells show 7-8 convolutions. Oospore—light yellow, showing 7-8 prominent ridges; 345μ long and 300μ broad. Membrane tuberculate.

Sardah, ten miles off Rajshahi Town.

4th January 1936 and 10th January 1936.

It is a rather slender plant, not more than 10-15 cm. high, growing in a shallow ditch at Sardah along with *Ceratophyllum* and *Naias*. It is a peculiar *Nitella* having certain special characteristics of its own by means of which it can be easily distinguished from all others. The sterile whorls have fairly long branchlets, whereas the branchlets of the fertile whorls are much shorter. The dactyls are unequal, usually two-celled, but one-celled and three-celled dactyls have also been found. The antheridium is very small. It can be sharply distinguished from the other heterodactylous species recently described by Groves and Groves & Stephens by the presence of a tuberculate oospore membrane and the very small antheridium.

Summary

A new *Nitella—Nitella tuberculata*—is described. It is characterised by dactyls of three different kinds and the oospore membrane showing tuberculate decorations.

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FURTHER REVISION OF RUTACEAE-AURANTIOIDIAE OF INDIA AND CEYLON[1]

(Revisio Aurantiacearum VIII)

BY

TYÔZABURÔ TANAKA

Received for publication on the 5th March, 1937.

In visiting India and Ceylon during the period of Nov. 6, 1935 and Feb. 16, 1936, the author made an investigation of Rutaceae-Aurantioideae in various localities, including forests of Nilgiris, Coorg, Mysore and Assam, and Citrus growing centres of the Punjab, Central Provinces, United Provinces, Bombay, Madras and Bengal. Twelve herbaria were visited and about 4650 herbarium sheets were examined and identified. The summing up of the result of this investigation is now on the way. It also needs revising former enumeration published in 1930. The final issue of so complete a work will naturally take a few years more. The most important finding of the present study is the clear diagnosis of various Citrus species which have so far never been successfully interpreted. The detailed accounts of these interesting features will be published from time to time in the present journal. Many species of Citrus relatives imperfectly known or misrepresented are properly dealt with in this paper. Geographical distributions of the wild species are also corrected in many cases, by actual investigation of local floras. The reference is also made here as to the new name or change of nomenclature since the former paper was issued (marked with asterisks). Literature where the original description of each species and synonym occurs is omitted, unless such citation is considered necessary.

MICROMELUM CEYLANICUM Wight: Tanaka in J. Bot. 68:225, 1930. Endemic to Ceylon, rather rare. Assam and Sikkim specimens reported before, must be a case of mis-identification.

MICROMELUM FALCATUM Tanaka in Bull. Mus. Paris, 2 sér. 2:156, 1930; in J. Bot. 68: 225, 1930. Burma, incl. Tenasserim, rare. (Rather common in Indo-China and southern China).

MICROMELUM HIRSUTUM Oliv.: Tanaka in J. Bot. 68: 225, 1930. Burma incl. Tenasserim and Shan States, not uncommon. (Occurs in Malaya). Both *M. Falcatum* and *M. hirsutum* seem not to occur in the Andamans.

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[1] Contributions from the Horticultural Institute, Taihoku Imperial University, No. 21.

MICROMELUM INTEGERRIMUM W. et A. ex M. Roemer in Fam. Nat. Reg. Veg. 1: 47, 1846: Tanaka 1. c. Common in Bengal, Sikkim, Assam, Burma and the Andamans. Occurs also in Nepal. Once collected by Royle in N. W. India, and by Gamble in Chota Nagpur, Bihar.

MICROMELUM PUBESCENS Blume: Tanaka 1. c. 226. Lower Burma incl. Tenasserim, very rare. It seems not to occur in the Andamans. (Common in the Malay islands.)

GLYCOSMIS BILOCULARIS Thw.: Tanaka 1. c. Endemic to Ceylon and the southernmost end of Peninsular India, rare.

GLYCOSMIS BOREANA Narayanaswami*[1]. Folia 5-foliolata, foliolis mediocris ovatis caudato-acuminatis, basi obtuse acuminatis, plus minusve longe petiolulatis, chartaceis, supra in sicco nigricante atro-virens, subtus pallidibus pellucido-punctatis. Inflorescentia paniculata majuscula pauciflora diffusa, floribus grandibus longe pedicellatis, calycibus 5-lobatis lobis sub-orbiculatis mucronatis, basi profunde sinuatis, petalis ovatis acutiusculis circiter 6.5mm. longis, filamentis late dilatatis, antheris glanduloso-apiculatis. Ovarium magnis lageniformis medio constrictum, apice in stylum attenuatis basi in gynopholum laxe expansus, stylus linearibus potius crassiusculis teretibus, usque dense ferrugineo-tomentosis, stigmate paulo capitato. Assam. Extremely interesting species allied with *G. chlorosperma* with large inflorescens and flower. The floral organ closely resembles that of *G. platyphylla* Merr. of the Philippines but very much larger. Filed in Calcutta Botanic Garden Herbarium without detailed collection remarks.

GLYCOSMIS CHLOROSPERMA Spreng.: Tanaka 1. c. Rarely occurs in Tenasserim. It does not occur in the Andamans. (Very common in Malaya and the Sunda islands.)

GLYCOSMIS CITRIFOLIA Lindl. :Tanaka 1. c. Occurs in northern Ceylon and the southernmost end of Peninsular India, extremely rare. (Common from Java to southern Japan). *Glycosmis macrocarpa* Wight, Illus. Ind. Bot. 1: 108, 1840, is in all possibility identical with *G. citrifolia*.

GLYCOSMIS CRAIBII Tanaka 1 c. Very rare Siamese species, once found in Burma.

var. *GLABRA* Tanaka 1. c. Same as above.

GLYCOSMIS CYANOCARPA Spreng.: Tanaka 1. c. Common in Assam and Sikkim, gradually decreasing in number in Bengal (incl. Chittagong), and Burma. Also occurs in Bhutan, and rarely found in the Andamans, which is called *G. pentaphylla* var. *fuscescens* (*Kurz*) Narayanaswami. The Burmese specimens are called *G. mansiana* Narayanaswami and *G. cymosa?* Narayanaswami in Calcutta Botanic Garden Herbarium.

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[1] These unpublished names of Mr. V. NARAYANASWAMI listed in this paper are based upon his determinavits attached to the specimens filed in various herbaria in India intended for a monograph of Indian *Glycosmis*. These valuable specimens are not found in any herbaria outside of India, so that these good species and varieties were first met with by the author.

var. ***LINEARIFOLIOLIS*** Narayanaswami*. Folia sparce 5-foliolata, foliolis linearibus longe acuminatis basi in petiolulis attenuatis, marginibus minute serrulatis. Inflorescentia compacta puciflora, floribus aggregatis, ovaliis cylindro-clavatis toto glabris, stigmate capitato nullo vel brevissimo. Very distinct variety occurring here and there in Assam. Assam Herbarium, Shillong, and Calcutta Bot. Gard. Herbarium. It resembles *G. longipes* Tanaka in Bull. Mus. 2 sér. t. II. 159 (1930), but the floral organ is entirely different.

GLYCOSMIS GREENEI Elmer var. *VIRGATA* Tanaka* in Med. Rijks. Herb. Leiden 69: 5, 1931. =*G. Parkerii* Narayanaswami in sched. Mergui in Burma, being rather unusual existence. (Occurs in Java and the Philippines).

GLYCOSMIS MAURITIANA Tanaka 1. c. Rather common in Ceylon and southern India (incl. Mysore.) Very rarely occurs in Bihar & Orissa, and Bengal. (Extends to Mauritius.)

var. *ANGUSTIFOLIA* Tanaka 1. c. It rarely occurs in southernmost end of Peninsular India and Ceylon.

var. ***ANDAMANENSIS*** (Narayanaswami)*=*G. pentaphylla* var. *andamanensis* Narayanaswami in sched. Only differences from the type by thinner texture of the leaflets with much less lustre on the surface and slightly larger inflorescence. The Andamans.

var. ***INSULARIS*** n. comb.* =*Glycosmis arborea* var. *insularis* Kurz in Hooker Journ. Bot. n. s. 5:38, 1876, proparte. Differs from the type by having tapering ends of the leaflets and smaller flowers, so that it approaches to *G. Greenei* of the Sunda islands. Rarely occurs in the Nicobar. (Seldom in Malacca.) *G. pentaphylla* var. *latifolia* Narayanaswami in sched. is identical with this.

GLYCOSMIS PARKINSONII Tanaka 1. c. 227. South Tenasserim in Lower Burma. (Rare species with two varieties, one from Sumatra, the other from Malaya).

GLYCOSMIS PENTAPHYLLA Corr.: Tenaka 1. c. Commonest species in India and Ceylon, distributing all over except Sikkim and the Nicobar. Most abundant in Peninsular India and Burma, finally reaching Yunnan at one end, and Mauritius and Madagascar at the other end. It does occur in Gharwal, Kumaun and the Punjab. It stops at South Andaman and seldom reaches to the Sunda islands. The systematic status of this species and *G. mauritiana* is as follows:

G. pentaphylla Corr. (1805)=*Limonia pentaphylla* Retz. (1789) =*Limonia arborea* Roxb. (1795). Leaflets lanceolate, serrate, filament dilated, ovary much pimpled.

G. *mauritiana* Tanaka (1928)=*Limonia mauritiana* Lam. (1789)=*L. pentaphylla* Roxb. (1795) non Rtetz.=*Glycosmis triphylla* Wight (1833). Leaflets ovate, shiny, entire, filament linear, ovary glabrous, stipitate.

var. **LINEARIFOLIOLIS** (Narayanaswami)* =*G. arborea* var. *linearifoliolis* Narayanaswami. Species typicae similis, sed foliola conspicue linearis. Cultivated in Forest Park, Dehra Dun and in Government Garden, Saharanpur; possibly a domesticated natural freak. Entirely different from *G. cyanocarpa* var. *linearifoliolis*.

GLYCOSMIS RUPESTRIS Ridley: Tanaka l. c. Rarely found in Lower Burma. (Rather rare species from Malaya, Siam and Indo-China).

GLYCOSMIS SAPINDOIDES Lindl. ex Wall. apud Oliv.: Tanaka l. c. Rarely occurs in the Andamans and Tenasserim: The Nicobar specimens belong to the next variety. (Malaya, the Sunda islands, Papua, Australia; never abundant.)

var. **PILOSA** (Narayanaswami)*=*G. pilosus* Narayanaswami in sched. Rufous pubescent on ovary and style as the type, which are much shorter in length. Leaflets lack pellucid dotting on the lower surface and are thin and crispate. The Andamans and the Nicobar.

GLYCOSMIS SINGULIFLORA Kurz* in Hooker Journ. Bot. n. s. 5: 37, 1876. Upper Assam, only once collected by Masters. Type specimen in Calcutta Bot. Gard. Herbarium. *G. parva* Craib is very near to this, but differs by having unifoliolate, pellucid-dotted leaves and round berry.

GLYCOSMIS WINITII Craib: Tanaka l. c. Mergui (and Siam), extremely rare.

CLAUSENA DENTATA M. Roem.: Tanaka l. c. Rather common in southern India and Ceylon. Rarely occurs in Assam, Sikkim, Upper Burma, Bengal (incl. Chittagong). (Very rarely found in China).

var. *PUBESCENS* Tanaka l. c. Ceylon and Mysore, very rare.

var. *ROBUSTA* Tanaka l. c. 228. Assam and Sikkim, rare. (Also found in Yunnan, Kwangtung, and Siam.)

var. *LONGIPES* Tanaka l. c. Upper Burma, very rare. (Found also in Siam).

CLAUSENA EXCAVATA Burm. f.: Tanaka l. c. Rather common in Assam, Sikkim and Burma, also from Bengal plains, northern Coromandel and Bihar. (Extremely common in Indo-China, Siam, Malaya, the Sunda islands and the Philippines. Not rare from Yunnan to Hainan, China, finally reaching to Formosa).

var. *VILLOSA* Hook. f.: Tanaka 1. c. Not uncommon in Burma. (Also from Siam, Indo-China and Malaya). Very rarely found in Nepal.

CLAUSENA HARMANDIANA Pierre: Tanaka 1. c. Once collected in Mergui, Burma. (A rare species found in Cambodia, Laos, Java and Bali).

var. *PAPUANA* Tanaka l. c. Rarely found in Lower Burma. (Also from Papua, Ceram-Laut and Siam).

CLAUSENA HEPTAPHYLLA W. & A.: Tanaka 1. c. Occasionally found in Bombay, Madras, Bengal, Assam, to Lower Burma (Mergui). (Rarely found in Siam, Annam, Tonkin, Malaya, the Sunda islands, and Timor).

CLAUSENA INDICA Oliv.: Tanaka 1. c. Bombay, Mysore, Madras and Ceylon, endemic.

CLAUSENA LANSIUM Skeels: Tanaka 1. c. Collected in N. W. India and Assam, probably cultivated. Gardens of Bengal, Bombay, Chittagong and Ceylon. (Native of China, Formosa and Indo-China).

CLAUSENA LEVIS Drake: Tanaka 1. c. Cultivated in Royal Botanic Garden, Calcutta. Seed from Burma? (Rare species from Tonkin, Laos and Siam).

CLAUSENA PENTAPHYLLA DC.: Tanaka 1. c. Upper Gangetic Plains, concentrated in northern U. P. (Oudh and Garhwal). (Once found in Siam).

CLAUSENA SUFFRUTICOSA W. & A.: Tanaka 1. c. 229. Assam, Bengal (Chittagong), and Burma, rather rare. (In China from Yunnan to Hupeh, also rare).

CLAUSENA WALLICHII Oliver: Tanaka 1. c. Assam and Burma, extremely rare. (Also collected from Siam).

MURRAYA GLENIEI Thwaites ex Oliver in Journ. Linn. Soc. Bot. 5, suppl. 2:29, 1861. =*Chalcas Gleniei* Tanaka 1. c. Endemic to Ceylon, rare.

MURRAYA KOENIGII Spreng. Syst. Veg. 2: 315, 1825= *Chalcas Koenigii* Kurz in Journ. As. Soc. Bengal 44 (2) : 132, 1875: Tanaka 1. c. Common in India and Ceylon, except Burma, where only rarely collected, while there is no collection from the Andamans and the Nicobar. It extends from Assam to Siam, Annam and Yunnan. (Collected from Java and Madagascar, probably cultivated. Very rarely cultivated in Malaya).

MURRAYA PANICULATA Jack in Maly. Misc. 1: 31, 1830 =*Chalcas paniculata* Linn.: Tanaka 1. c. The commonest species distributed all over India and Ceylon, incl. Burma and the Andamans (not from the Nicobar). Also collected from Nepal and Bhutan. (Very common in the Sunda islands and the Philippines, also reaching Siam, Indo-China, Yunnan, Formosa, Amami-Oshima, Moluccas, as far as New Caledonia, Mauritius, Seychells, and Madagascar).

var. *ZOLLINGERI* Tanaka* =*Chalcas paniculata* Linn. var. *Zollingeri* Tanaka in Bull. Soc. Bot. France sér. 5. 4: 710, 1928. Cultivated in Peradeniya Bot. Gard. Ceylon.

MERRILLIA CALOXYLON Swingle: Tanaka 1. c. Once found in Pegu in Burma. (Rather common in Malaya, rare in Sumatra).

FERONIA LIMONIA Swingle: Tanaka 1. c. Ceylon, South India, Upper Gangetic Plains, and Western Himalaya, rather rare. Also rare in Bihar and Orissa, Bengal, and western Upper Burma. (Almost no collection from Siam, Indo-China, Malaya and the Sunda islands).

FERONIELLA PUBESCENS Tanaka in Bull. Mus. Paris 2 sér. 2: 161, 1930: Tanaka 1. c. Not rare in Burma. (Found rarely in Siam and Java).

AEGLE MARMELOS Corr.: Tanaka 1. c. 230. Common; most abundant in Peninsular India. Occurs in western Himalaya, W. Nepal, Sikkim to Burma. Only once collected in Assam. Not found in the Andaman and the Nicobar. (Rarely seen in Siam, Indo-China, Malaya and the Sunda islands).

TRIPHASIA TRIFOLIA P. Wils.: Tanaka 1. c. Rather wild in the Andamans and the Nicobar, and probably in Peninsular India and northern Ceylon. (More common in the Philippines and the Sunda islands; rare in Indo-China).

HESPERETHUSA CRENULATA M. Roem.: Tanaka 1. c. Peninsular India, N. W. provinces, western Himalaya, Bengal and Lower Burma: Not common. (Rarely found in Siam, Annam and Laos).

LAVANGA ANGUSTIFOLIA Tanaka 1. c. Endemic to Ceylon, rare.

LAVANGA ELEUTHERANDRA Dalz.: Tanaka 1. c. Only in Peninsular India, not rare.

LAVANGA SARMENTOSA Blume: Tanaka 1. c. Once collected in Lower Burma. (Common in Malaya, the Sunda islands and Borneo).

LAVANGA SCANDENS Buch.-Ham.: Tanaka 1. c. Rather common in Assam. (Also from Siam, Indo-China and Malaya, rare).

PARAMIGNYA ANDAMANICA Tanaka 1. c. Not uncommon in the Andamans and the Nicobar. (Also from Malaya, Sumatra, Borneo, Annam and Cochinchina, rare).

PARAMIGNYA ARMATA Oliver: Tanaka l. c. Endemic to Ceylon, rather rare.

PARAMIGNYA BEDDOMEI Tanaka l. c. Endemic to South India, rather rare.

PARAMIGNYA CITRIFOLIA Hook. f.: Tanaka l. c. Only found in Bengal. (Occurs rarely in Malaya and Annam).

PARAMIGNYA GRANDIFLORA Oliver: Tanaka l. c. Lower Burma, rare. (Also from Malaya and the Philippines, rare).

PARAMIGNYA MONOPHYLLA Wight: Tanaka l. c. Ceylon, Peninsular India, Sikkim, Bhutan, and Assam, not uncommon.

PARAMIGNYA SCANDENS Craib: Tanaka l. c. Assam and Burma, rather scarce. (Also from Siam, Laos, Malaya and Hainan in China, rather rare).

PAMBURUS MISSIONIS Swingle: Tanaka l. c. Madras and Ceylon, rather rare.

PLEIOSPERMIUM ALATUM Swingle: Tanaka l. c. Madras and Ceylon, not uncommon. Rarely found in the Andamans.

MEROPE ANGULATA Swingle* in Journ. Wash. Acad. Sci. 5: 423, 1915. Bengal and Burma, rare. (Also from Malaya, Java, New Guinea and the Philippines, rare).

ATALANTIA CEYLANICA Oliv.: Tanaka l. c. 232. Ceylon and southernmost Pen. India, endemic.

ATALANTIA RACEMOSA W. et A.* Pr. Fl. Pen. Ind. Or. 1: 19, 1834. Ceylon, Madras, Mysore, Coorg, and Bombay, rather common. This species was omitted in the previous paper by mistake.

ATALANTIA ROTUNDIFOLIA Tanaka l. c. Ceylon and Madras, very rare. (Once found in Annam).

ATALANTIA SIMPLICIFOLIA Engl. em. Tanaka l. c. Assam and Burma, rather rare.

ATALANTIA MALABARICA Tanaka* n. comb.=*Malnerega malabarica* Raf. Syl. Tell. 143, 1838=*Atalantia spinosa* Tanaka l. c. non Koorders=*Atalantia platystigma* Wight Illus. Ind. Bot. 1:108, 1840=*Atalantia floribunda* Wight Icon. Pl. Ind. Or. 4: 1611, 1850 =*Limonia monophylla* Roxb. Pl. Corom. 1 : 59, 1795, non Linn.= *Trichilia spinosa* Willd. Sp. Pl. 2:554, 1799=*Atalantia monophylla* (Roxb.) DC. Prod. 1 : 535, 1824.

The name proposed by the author in 1930 is not to be used on account of the presence of *Atalantia spinosa* Hook. ex Koorders Exkursionsfl. Java 2 : 427, 1912=*Sclerostylis spinosa* Blume Bijdr. Fl. Java 3 : 134, 1825=*Merope angulata* Swingle in Journ. Wash.

Acad. Sci. 5(12) :423, 1915. Linné's *Limonia monophylla* Mant. 2: 237, 1771, cannot be applied to the present species as the source of new combination, since it means solitary-flowered *Atalantia buxifolia* Oliv.=*Severinia monophylla* Tanaka, given below. Very common all over India and Ceylon, including Burma, the Andamans and the Nicobar, and excluding Himalaya region, Assam, and Gangetic Plains. (Also from Siam, Malaya, Indo-China and Bangka islands).

ATALANTIA WIGHTII Tanaka l. c. N. Canara in Bombay, Mysore and Madras, rather common.

SEVERINIA MONOPHYLLA Tanaka l. c. Cultivated in Bengal and South India. (Indo-China, South China, and Formosa).

EREMOCITRUS GLAUCA Swingle* in Journ. Agr. Res. 2 : 86, 1914. Cultivated in Peradeniya. (Native of Australia).

FORTUNELLA MARGARITA Swingle: Tanaka l. c. Cultivated. Specimens from Poona, Calcutta, and Saharanpur. The oval kumquat is not known to Bonavia, being a later introduction. Mostly planted for ornamental purpose.

FORTUNELLA CRASSIFOLIA Swingle* in Journ. Wash. Acad. Sci. 5 : 173, 1915. Cultivated. Specimen from Saharanpur. The Meiwa kumquat must also be recent introduction. It makes a good fruit preserve as the former.

CITRUS AURANTIFOLIA Swingle: Tanaka l. c. Common lime (Kaghzi nimboo), cultivated everywhere but no wild growing was found in Peninsular India, as so supposed. The only possibility of wild occurrence of the lime is in Upper Burma. This is the most valued Citrus for culinary use, medicine, beverage, and lime-juice. Unquestionably several varieties are in existence: The most conspicuous variety is the following:

var. **PYRIFORMIS** (Lush.) n. comb.*=*Citrus acida* var. *pyriformis* Lushington in Ind. Forester 36 : 341, 1910. Very remarkable variety with lemon-like leaves, very long-shaped fruit, thicker rind and large flat seeds. Bahari nebu from U. P.

CITRUS AURANTIUM Linn.: Tanaka l. c. The cultivation of true sour orange (Seville orange) was varified by the author in Assam (Soh tang), Madras (Naradabba), Mysore (Herale), Bombay and the Punjab (Khatta). The fruit is valued for its medicinal property and is generally used for marmalade and confection. The seedling is used for rootstocks grafting sweet oranges and lemons.

CITRUS CHRYSOCARPA Lush.* in Ind. Forester 36(6/7) : 343, 1910=*C poonensis* Hort. ex Tanaka l. c. 234=*Citrus Khasya* Marc. in Trud. Prikl. Bot. 24:434, 1931. This is commonest commercial Citrus fruit of India, Burma and Ceylon, and the same as the famous Ponkan of southern China and Formosa. It is the Sùntara (Santra) of Nagpur, Poona and the Punjab, Kamala of Bengal, Walaja Kamara of Madras, Emmey Doddy or Kadug Ärange (Coorg orange) of Mysore, Kittale hanno of Coorg, Soh Niamtra or Soh myntra or Shantara of Assam, Jamanaran of Ceylon, etc. Standardized name is necessary at least for India. Probably originated in Shan State in Burma as a cultigen, where it is called Kambala-thi, according to Brandis's collection. It is the most valued market fruit in India extending to 4,000 ft. from sea level. In flat land, two consecutive crops are obtained by application of drastic root exposure process, through which off-season blooming is effected.

CITRUS CRENATIFOLIA Lush.* in Ind. Forester 36 : 343, 1910. The Keonla or Kawla in U.P., the Punjab and Poona. Closely resembles Ladoo (*C. paratangerina*) but it has pulp vesicles arranged gathering to the mid-line in transversely halved fruit. Occasionally cultivated for fresh fruit but it is inferior to the former.

CITRUS DELICIOSA Ten.* in Ind. Sem. Hort. Bot. Neapol. 1840, p. 9. The Mediterranean mandarin. Cultivated for local consumption of fruit in the United Provinces, as reported by Bonavia. Introduced from Europe.

CITRUS ERYTHROSA Hort. ex Tanaka in Mem. Tanaka Cit. Exp. Stat. 1(1): 30, 1927. var. ***ASSAMICA*** Hort.* nov., fructibus parvis subglobosis compressisque glabris exmammillatis rubro-aurantiacus, apice minute foveolulatis, cortice tenui. It lacks the apical projection characteristic to the type species and the color of rind is not sufficiently vermilion. Other points, i.e., the size and the shape, segments, pulp and seed characters, etc., all agree with the type. Soh Siem in Tyrna near Cherrapunji, Assam, rare. Fruits for local consumption, having little value for marketing.

CITRUS GRANDIS Osbeck: Tanaka 1. c. The shaddock. Chakotra of Bombay, the Punjab & Peninsular India, Batavi lebu of Bengal. Cultivated in many places for fruit. Brandis collected it (wild?) in Damra ghat in Garo Hills, Assam. Probably wild also in eastern Burma, reaching to Yunnan and Tonkin. The author met with several varieties with particular characteristics never found outside of India. *Aurantium maximum* Burm. Index Univ. Herb. Amb. (p. 16), 1755, as the source of new combination, cannot be admitted since the author gives more widely recognized specific name *Citrus decumana* to the same species in the earlier part of the same work (p. 11), so that the incidental use of this particular name is not valid. The same author therefore withdrew it and substituted *C. decumana* to it in his later work, Index Alter in Omnes Tomos Herbardi Amboinensis (p. 16), 1769.

CITRUS INDICA Tanaka 1. c. It is really a wild Citrus found in Nowgong District, Khasi Hills and Manipur in Assam. It belongs correctly to *METACITRUS*, as was predicted by the author, having small sized fruit with thin reddish rind and very slimy pulp, much similar to that of *Citrus depressa* Hayata. Perhaps of value as a rootstock.

CITRUS JAMBHIRI Lush. l. c. p. 342. The Jambhiri of C. P., U. P., and Bombay, Khatti of the Punjab, Kada Narangai of Coonoor. (The Florida Rough of U. S. A.). It seems to grow (wild?) in Almora. There is an acidless form, having no morphological difference (Lyallpur Agr. Coll.).

CITRUS KARNA Raf.* Syl. Tell. 142, 1838=*Citrus dimorphocarpa* Lush. in Ind. Forester 36:346, 1910. A cultigen rather commonly cultivated in western part of India. The Khatta, Karna, or Id lemon of Bombay, U.P., & the Punjab.

CITRUS KINOKUNI Hort. ex Tanaka* in Mem. Tanaka Cit. Exp. St. 1(1):31, 1927. The Kinokuni (Kishû Mikan) of Japan, cultivated in Saharanpur under the name "Kymo Kasi". Only planted for trial and the fruit is too small for commercial use.

CITRUS LATIPES Tanaka l. c. The Soh Kymphor (Soh Comphor) of Assam. Wild in Naga Hills and Khasia. This is probably of great value as a rootstick of the loose-skin oranges, as the habit of tree very much resembles that of *Citrus Junos* Sieb. of Yunnan origin, the valued rootstock plant of Japan.

CITRUS LIMETTA Risso* in Ann. Mus. Paris 20:195, 1813. Common Lumia of Italy, cultivated in Springfield Place in Coonoor. By the presence of distinct flat areola, it is unmistakable with the Jambhiri, but it also has even rind, solid central column, and stiff acidless linear pulp vesicles. Entirely different from the Sakhar nimboo (Mitha nimboo) commonly cultivated. This is the first time reported from India, probably of introduced origin from Europe. The use of the fruit as below.

CITRUS LIMETTIOIDES Tanaka* sp. nov., (Sect. Citrophorum) foliis ovatis vel ellipticis utrinque obtusis saepe cum mucrone brevi, basi subrotundatis vel acutiusculis, petiolis nudis, fructu subgloboso aut ellipsoideo laevissimo sulfureo, apice rotundato excolonato interdum inconspicue apiculato, cortice tenuissimo, pulpa dulci exaromatica, seminibus elongatis frequenter angustissimis, cotyledonibus non nunquam atroviridis.

Sakhar Nimbu in Poona & Nagpur, Mith of Lahore, Shi Nimbe of Mysore and Coorg, Soh phai in Assam. Commonly cultivated and differs from the true *C. limetta* in leaf which is more like the lime, but not winged; fruit is like *C. limonia*, larger in size but seed character is much similar; rind is not oily and thick as in *C. limetta*, and lacks strong apical areola characteristic to it. All previous authors consider it to be identical with the Mediterranean *C. limetta* without actual comparison, but the latter is more like the true lemon, *C. Limon*, while the former lies half way between *C. aurantifolia* and *C. limonia*. Both *C. limetta* and *C. limettioides* have white flowers, acidless pulp and light-coloured tegmen at chalaza. Such retrogressive characters occur also in *C. medica, C. jambhiri,* etc. Bonavia states that this is the acidless form of the sour Kalan-kaghzi. It is eaten as a refreshing fruit especially in late summer when other Citrus fruits are scarce. Known also as refrigerant in fevers and jaundice.

CITRUS LIMON Burm. f.: Tanaka 1. c. The true lemon found wild in Almora: The Hill lemon of Saharanpur. Bonavia states that he introduced Malta lemon in 1863, and sent to Assam, Calcutta, Bangalore, Tinnevelly and the Punjab. It is used as the substitute of the lime, but the fruit is too big to be used as cheap culinary fruit. The culture is recommended as it is more resistant to the die-back than the lime and the oil of the rind is much valued as merchandise.

CITRUS LIMONIA Osbeck: Tanaka 1. c. Found cultivated here and there; globose orange-colored form from Poona (Sherbette), large yellow globose form the Punjab (Jatti Khatii and Jullunduri Khatti); deep yellow apiculate form from Mercara, Coorg (Maduli) and Assam (Jamir); orange-colored acidless form from Lyallpur, in the Punjab. The Rungpur Lime of Roxburgh and later authors occasionally cultivated in Europe and America. Surkh Nimboo may be a form of this species. (Known in southern China, Indo-China and Formosa. Japansch Citroen in Java. The last acidless form is found also in Malaya). Used as above, but the rind lacks the so-called lemon odour.

var. *KHATTA* Tanaka* in Bult. Sci. Fak. Terk. Kjusiu Imp. Univ. 1(3) : 114, 1925; excl. syn., fructibus oblongis mamillatis rubro-aurantiaceis, cortice duro subcrasso, pulpa acida. Introduced into Alger, Algeria from India under the name Khatta: Found cultivated in Assam under the name Khata lebu or Large Jamir. Soh Jaw of Assam covers both the type and this variety.

CITRUS LYCOPERSICAEFORMIS Hort. ex Tanaka* in Stud. Citrol. 7 (1) :68, 1935 = *Citrus crenatifolia* var. *lycopersicaeformis* Lush. in Ind. Forester 36: 343, 1910. Heen naran in Ceylon, Kokni of U. P., Kodangithuli in Coorg, southern India. Very much resembling *C. amblycarpa* of Java in having sinuate fruit apex, but this has thicker rind and coarse-netted vesicles edible in full ripe. The Javanese species never gets bright orange color, and the rind is thinner, pulp vesicles much linear, lighter in color and more acid. Rarely sold in the market but the fruit is of little value. Perhaps it is the only wild Citrus in Nilgiris and Coorg.

CITRUS MACROPTERA Mont.* in Mém. Acad. Lyon 10:187, 1860. Found in Burma, Salween 2,500 ft. by D. Brandis (Herb. Univ. Hamburg.) (Rare in Malaya, Sumatra, Borneo and Celebes, but very common in the Philippines. This is the only Citrus reaching to New Caledonia).

var. **COMBARA** (Raf.)* n. comb. = *C. Combara* Raf. Syl. Tell. 142, 1838 = *C. macroptera* var. *annamensis* Tanaka in Bull. Mus. Paris 2 sér. 2:163, 1930; l. c. p. 233. Rafinesque's original description of *Citrus Combara* reads "Pet. dilatato alatis, fol. subrot. crenatis, ad pet. subequalis—singular sp. with strong thorns and petioles nearly similar to leaves in size and shape, called Combara in India." This undoubtedly refers to this variety, as the related species *C. latipes* does not have nearly round lamina. The Burmese name "Combara" (Kambala thi?) seems to apply to other species, such as *C. chrysocarpa*, according to the specimen collected by Dr. Brandis. This very peculiar variety occurs here and there in Assam and known under the name Soh Kwit (Soh Quid), also collected from Kuma'on, U P., Burma, Siam and Annam. The fruit is stored and used for refreshing drinks when other small acid Citrus fruits are gone.

CITRUS MADERASPATANA Hort.* nov., fructibus globosis verrucosis aurantiaceis, apice areolatis, basi interdum mamillatis, cortice subcrasso fungoso odorato, segmentis aequalibus inflatis, pulpa flava succosa dulci subamaro acidula, vesiculis quinquangulari-reticulatis congestis polyspermis, seminibus mediocris obovoideis subrostratis cremeo-stramineis reticulatis, tegmentis testaceis apice vinoso-latericis, embrionis binis dilutissime flavo-virens. The Kitchli of Madras, commonly cultivated for local consumption. It is said that the pulp turns sweet and quite edible. Plant very much like the sour orange (*C. Aurantium*) with leaves broadly winged. More detailed description will be given when good material is available. (See Bonavia Pl. CVI).

CITRUS MEDICA Linn. Tanaka l. c. p. 234. Common citron, including small acid fruited Bajoura, large acid fruited Turunj, and large sweet fruited Madhkankur. The sweet pulped "Mahdala" from Mercara, Coorg (Citron for pickle) has distinct winged petiole and white tegmen of seeds. The wild nature of the citron in South India is not distinct, but it is more decisive in eastern India and Burma. The fruit is commonly used as refrigerant, pickling and preserves.

CITRUS MICROCARPA Bunge: Tanaka l. c. Hazara of Benares, erroneously called Kumquat in Delhi, Bangalore, etc. This is the Calamondin of the Philippines, Limau casturi of Malaya, Shikikitsu of Japan and China. Good ornamental pot plant in Delhi, Lahore and other places.

CITRUS NATSUDAIDAI Hayata Icon Pl. Formos. 8:29, 1919. The Natsudaidai of Japan, often under cultivation, in the Punjab, C. P., U. P. and Madras, with the name Watson Pomelo. This is a cheep summer orange and may be valuable as the substitute for the grapefruit.

CITRUS NOBILIS Lour.* Fl. Cochinch. 466. 1790. The King orange cultivated only for trial in Saharanpur.

CITRUS PARADISI Macf. Fl. Jam. 1:131, 1873. The grapefruit, cultivated in Poona, Nagpur, Allahabad, Saharanpur, Lyallpur, etc., also to some extent on commercial scale in the Punjab. The highly valued refreshing breakfast fruit. The canned pulp is valued as a salada and the juice is canned like the sweet orange juice.

CITRUS PARATANGERINA Hort. ex Tanaka* in Studia Citrol. 7(1):68, 1935, foliis minutis ovatis obovatisque subrotundatis, apice obtusis saepe emarginatis, basi subacutis, petiolis longiusculis linearibus, fructibus globosis basi-manillatis, apice late-concavis exareolatis sublaevibus miniato-aurantiaceis, cortice tenui, segmentis intus apiculatis, pulpa lutea dulci, vesiculis nunquam ad medium loculisque confertis. The Ladoo of Poona and the Punjab. Occasionally cultivated for fresh fruit as a kinsman of *Citrus crenatifolia* Lush. A comparison with other species will be made in a later publication. The drawing of Bonavia Pl. CXXVI is not well represented.

CITRUS PENNIVESICULATA Tanaka* n. sp. = *Citrus megaloxycarpa* Lush. var. *pennivesiculata* Lush. in Ind. Forester 36:345, 1910, foliis majusculis oblongo-ovatis, crenato-serratis, petiolis obovato-alatis, fructibus magnis sub-globosis depressis costatis citrinis, costulis numerosis, cortice tenui coriacei, segmentis plurilocularis, pulpa hyalo-viridula denique sulfurea acida, vesiculis elongatis numerosis assidue penniformibus exhibens. Common Gajanimma of Madras, Bandhuri of Coorg, and Attara of C. P. Bonavia Pl. CCX correctly refers to it. It is used mostly for culinary purposes.

CITRUS RESHNI Hort. ex Tanaka in Stud. Citrol. 7 (1):68, 1935 = *Citrus Aurantium* subsp. *Keonla* Engl. var. *Reshni* Engl. in Engl. Pl. Pflazenf. 3(4) :200, 1897. Chota Kitchli, commonly cultivated in the vicinity of Madras, identical with Reshni of Lucknow (Bonavia Pl. CXXII), and was identified by the author to be exactly the same as the Cleopatra orange of Florida. Fruits are consumed locally having little commercial value.

CITRUS RUGULOSA Hort.* nov. = *Citrus chrysocarpa* Lush. var. *decumana* Lush. in Ind. Forester 36:344, 1910, fructibus magnis pyriformibus reticulato-rugulosis, inconspicue remote punctatis flavo-luteis, apice sinuato-excavatis, basi rugosissimis, cortice crasso oleifero albido, segmentis extus emarginatis, intus minute mucronatis, pulpa mellea acidula subamara non-sapida, vesiculis oblongo-linearibus acutis parallelibus instructis, seminibus majusculis obovatis striatis compressiusculis stramineis, tegmentis fulvis, apice castaneo-umbrinis, embryonis plurimis albidis. The Attani from Saharanpur. Leaves rather small in contrast with the large-sized fruit, the crenation of margin is almost inconspicuous: Petiole linear with very narrow cuneiform wing. The cultigen belongs to Sect. Aurantium and much like *C. Natsudaidai* in nature, but differs in decided pyriform shape with much wrinkled surface, and in other detailed characters. Bonavia Pls. CX to CXIII fairly well represent this. Very poor orange of inferior eating quality.

CITRUS SINENSIS Osbeck: Tanaka 1. c. The sweet orange, probably native to eastern Burma (Tung-chin-thi, according to Brandis) and reaches to Yunnan and Tonkin in its distribution. Rarely cultivated in Sikkim and other Himalayan region. Malta orange of the Punjab, Mosambi of Bombay, and Chinee (Batavia orange) of Madras are of introduced origin as their names indicate. It is called Satladi in Coorg. In Assam, a closely allied species called Soh Niangling occurs in native gardens. The well-known and most valued commercial Citrus of the world.

CITRUS TANGERINA Hort. ex Tanaka 1. c. Hyderabad Kamala of Madras is the typical tangerine of the United States. Introduced varieties such as Dancy and Beauty of Geln Retreat are also cultivated in U. P. Fruits are inferior to *C. chrysocarpa* but may be valued as a cheap local fruit.

CITRUS UNSHIU Marc. in Isv. Sochin. Sukh. St. 2:5 1921. The Satsuma orange of Japan. Cultivated in Lal-Bagh Garden, Bangalore. The best commercial Citrus fruits of the warm temperate region. The canned pulp is highly valued in Europe as the material used in confectionary.

Concluding note: The great majority of the representative genera and species of Rutaceae-Aurantioideae occurs in India. Six years ago, the author enumerated 18 genera, 70 species and 9 varieties of this sub-family from India and Ceylon, but actual investigation in field and herbaria resulted in the discovery of 19 genera, 93 species and 16 varieties. The total number of species mentioned here is double the number of the species presented by Oliver in 1861. There are still some species not known to the writer, such as the Amilbêd (*Citrus megoloxicarpa* Lush.) and the Sadaphal (*Citrus semperflorens* Lush.) It is therefore highly desirable for the writer to receive further information or sufficient plant materials of them for detailed studies of these interesting members of the genus.

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REVIEWS

BOULENGER, G. A. REVISION DES ROSES D'ASIE. (Asiatic Wild Roses) Bull. Jard. Bot. de l'Etat, Bruxelles, vol. 11: 203-279, 1933. vol. 13: 65-266, 1935; vol. 14, 115-221, 1936.

Since the time of Linnæus, the genus *Rosa* has been recognised as a difficult taxonomic problem. We are indebted to Dr. G. A. Boulenger, F.R.S., who, after attaining world-wide renown as a herpitologist and ichthyologist, has, since his retirement from the British Museum, devoted his talents and experience as a systematist for over fifteen years to clearing up the unwieldy accumulation of species in *Rosa*.

Dr. Boulenger has found that the disc of the hypanthium and its orifice through which the styles pass are important and useful taxonomic characters which have been overlooked by former workers in the genus. His appraisal of other characters and the methods he uses to determine phylogenetic relationships and to delimit species agree with those used by myself in the revision of the American roses. Although he approached the problem as a systematist and I attacked it from the genetical and ecological side we both arrived at very similar conclusions.

This painstaking work has been done at the herbarium of le Jardin botanique de l'Etat in Brussels where Crépin's large collection of wild roses is deposited. From 1924 to 1932 the author published a revision of the roses of Europe, and then turned his attention to those of Asia. He has examined the material in all the larger herbaria in Europe and has devised a new classification of the genus based on seven sections, all of which are represented in Asia. The largest, the *Eglanteriae*, is divided into seven groups and in it all of the polyploid species are found. The polyploid roses are most boreal in range and the least specialized morphologically in America, Europe and Asia.

The great value of this revision both to rhodologists and field botanists lies in the practical recognition of parallel variations and polymorphism which has resulted in a welcome and useful reduction in the number of forms admitted to specific rank. Dr. Boulenger recognises 10 species in Europe and North West Africa, and 93 species in Asia of which 15 are found on other continents also. In the revision of the American roses I concluded that there were 20 native species, 2 of which range in Asia also. This gives a total of 121 species for the entire genus[1]. Each part of this revision is fully indexed and the fact that 420 specific and varietal names are listed in connection with the

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[1] Boulenger, G.A. Liste des Roses d'Asie, suivie de quelques remarques sur les rapports phyletiques entre les especes du genre *Rosa*. Ann. Soc. scient. Bruxelles. Serie B. vol. 56; 235—241. 1936.

93 Asiatic species gives some idea of the specific inflation which existed previously and the great amount of work involved.

Analytical keys to all species are given under the sectional headings. Under each species an exhaustive list of synonyms is given with full bibliographic references followed by a detailed description in French. The minimum and maximum numbers of serrations on each side of a leaflet, and frequently of stamens are recorded. The geographic ranges are defined as far as possible.

When the chromosome number has been published this is also given but is not always included in the description; in a few instances it is mentioned in connection with another related species. Occasionally the author has had to infer the dentity of the specimens used by Täckholm and Hurst in their cytological studies, a difficulty that applies to one of the Indian species. *R. macrophylla* Lindl was found to be diploid by Hurst and Täckholm who both obtained their material from a specimen at Kew which probably belongs to *R. Webbiana* Wall. *R. macrophylla* var. *Korolkowii* Hurst, and two other varieties, are tetraploid according to Hurst, and these Boulenger considers to be true *R. macrophylla*. If *R. macrophylla* is tetraploid it agrees with *R. alpina* L, of which Boulenger now makes it a variety. It is possible that this rose may also have a hexaploid strain indistinguishable morphologically, just as *R. acicularis* Lindl. in America may be hexaploid or octoploid, since *R. Sweginzowii* Koehne and *R. Moyesii* Hemsl. & Wils., which Boulenger places as synonyms of *R. macrophylla*, were found by Tackholm to be hexaploids.

This latest classification of the genus approaches a phylogenetic arrangement more nearly than has any other. Sections II-VI all consist of species somewhat specialized morphologically and which have usually a more southern range than those of Section I, none of which is found south of the Himalayas. In the last volume of the revision all the sections and species are listed in phylogenetic order. *R. persica* Michx., which has simple leaves, has not been included in the list because the author has decided that it belongs to another genus *Hulthemia* Du Mortier.

The genus *Rosa* is circumpolar and probably of Sub-arctic origin. Most of the tropical representatives belong to the sections *Synstylae*, *Banksianae* and *Bracteatae*, they are diploids and more evolved than the northern forms in the *Eglanteriae*. Because polyploidy is present in several of the primitive boreal species and in none of the southernmost species Boulenger has given his support to Täckholm's old theory of a hypothetical, extinct, Arctic decaploid rose to account for the irregular polyploid species, and likewise to Hurst's theory of the descent of diploids from polyploids in *Rosa*[2].

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[2] In my opinion neither hypothesis is necessary for reasons given elsewhere. Erlanson, E.W. Phylogeny and Polyploidy in Rosa. New Phyt. 1937 (in press).

A synopsis of the distribution of the species and varieties in the sections is given in Table I. Of the 18 new species described for Asia one, *R. Nanothamnus* is Indian.

Table I.

Number of Asiatic Rose species by sections.

Section.		Total Species.	Total Vars.	New Species.	Indian Species.
Eglanteriae	..	29	26	7	6
Chinensis	..	3	0	1	1
Synstylae	..	36	11	10	3
Banksianae	..	4	0	0	0
Bracteatae	..	2	0	0	1

There are 11 species attributed to India. Others will doubtless be described when more collections are made in the Himalayan regions. All but two of these species are confined to the mountains in the north.

List of Indian Rose species.

Section I. Eglanteriae.
Group A. Pimpinelli-Suavifoliae.

1. *R. sericea* Lindl., diploid; Himalayas: Sikkim to Simla and Koumaon; var. *Hookeri* Regel, Koumaon.
2. *R. Webbiana* Wall., diploid; Himalayas: Simla to Koumaon and Kashmir; var. *Winterbottomii* (Crép.) Bouleng. Type loc. Niti, Garhwal.
3. *R. Nanothamnus* Bouleng., diploid; Type loc. N. W. Frontier.

Group C. Alpinae-Vestitae.

4. *R. alpina* L., tetraploid; Himalayas; var. *macrophylla* (Lindl.) Bouleng., tetraploid and hexaploid; Himalayas from Sikkim to N.W. Frontier.

Group G. Gymnocarpae.

5. *R. Beggeriana* Schrenk., diploid; Baluchistan.
6. *R. Kotschyana* Boiss., diploid (?); Baluchistan.

Section II. Chinensis.

7. *R. gigantea* Collett, diploid; Manipur.

Section III. Synstylae.

8. *R. moschata* Herrm., diploid; Himalayas throughout.
9. *R. longicuspis* Bertol., diploid; Khasia and Naga Hills.
10. *R. Leschenaultiana* (Thory) Wight at Arn., diploid; Nilgiri and Pulni Hills.

Section V. Bracteatae.

11. *R. clinophylla* Thory, chromosomes unknown. Plains of Bengal; Himalayas.

Excluded species.

R. chinensis Jacq. found in the Nilgiri Hills, probably introduced.

R. Lyelli Lindl. of Nepal is believed by Boulenger (in agreement with Crépin) to be a natural hybrid, *R. clinophylla* × *moschata*. This crossing should be made experimentally.

Further Investigations Needed.

Dr. Boulenger has cleared up the tangled confusion which existed among the species of *Rosa*, but the Asiatic roses deserve further attention. Many forms of horticultural value no doubt still remain to be discovered. *R. gigantea* is the possible ancestor of the Tea Roses, and the related *R. chinensis* has given us the pink and crimson China Roses. An effort should be made to collect seeds from these and other Himalayan species and to grow large cultures of seedlings so that interesting and useful variants may be selected.

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STUDIES ON THE RESPIRATION OF *EUGENIA JAMBOLANA* LEAVES WITH RESPECT TO THEIR SUGAR, ACID, AND CATALASE CONTENT

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An attempt has been made in this paper* to establish a correlation between the intensity of respiration and the chemical contents of the leaves of *Eugenia Jambolana.* For respiratory activity Haldane's gas analysis apparatus together with the special type of aspirator as used by the author (1), was employed. For the study of chemical contents the following apparatus and methods were employed.

I. *Determination of pH values of Eugenia leaves of different ages:—*

The *Eugenia* leaves come out in pairs and both individuals of a pair may be considered to be of the same age. Out of one particular pair, one was placed in the experimental chamber for respiration while the other was crushed for the determination of pH values.

1 gm. of material was cut off from a leaf and was crushed in a clean glass pestle and mortar. The crushed material was thoroughly mixed with 50 c.c. of distilled water and centrifuged for 10 minutes. The clear liquid was decanted off and its pH value was determined

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* A part of the Thesis approved for the degree of D. Phil. of the University of Allahabad.

electrometrically with a Cambridge H-ion apparatus. As a precaution all the leaves for this section were brought from the garden at the same hour of the day; the solution used was accurately of the same strength; and the time devoted for weighing, crushing, and centrifuging was, as far as possible, the same in each experiment.

II. *Determination of total acid values of leaves of different ages:—*

5 gms. of fresh leaves approximately of the same age as those conducted for respiration experiment were weighed and carefully ground in a clean pestle and mortar. The crushed material was thoroughly mixed with 70 c.c. of distilled water and was then centrifuged.

After removal of the supernatant liquid the residue was again pounded with 30 c.c. of water and centrifuged. From the total volume of 100 c.c. of the solution 10 c.c. was now mixed with 40 c.c. of distilled water. 25 c.c. of sodium hydroxide of N/500 strength and a few drops of phenophthalein was added to the new mixture. This whole mixture was then titrated against weak oxalic acid of N/500 strength.

Total acid values of red and green *Eugenia* leaves were also noted after each 11 hours in the same way.

III. *Determination of catalase activity of leaves of different ages:—*

The catalase activity of *Eugenia* leaves was determined by the method of Ranjan & Mallik (4).

IV. *Determination of sugar content of leaves of different ages:—*

Pavy's method (2) was employed for the estimation of sugar.

Chemical contents of Eugenia leaves of different ages

I. *Determination of pH values:—*

Fresh leaves brought from the garden were immediately weighed and crushed. The pH values were determined electrometrically.

The following is the table of pH values of leaves of different ages:—

TABLE I

—	Different ages of leaves	pH values
1	Youngest leaves (2 days old)	4.62
2	Very young leaves (5 days old)	4.82
3	Moderately young leaves (10-12 days old)	4.73
4	Leaves turning green (15-20 days old)	5.90
5	New green leaves (1 month old)	6.83
6	Old green leaves (6 months old)	7.10
7	Old yellow leaves (about to fall out)	7.10

The pH of the cell sap, however, varies according to the time the leaves are kept in dark. In the case of fresh, young and red leaves the pH was 4·65 and after 4 days in darkness it was 5·85.

Similarly, the pH values of new green leaves were also determined. Here the pH values rise from 6·74 to 6·86 in 4 days in dark.

II. *Experiment on the total acid content:—*

It has been pointed out by many workers that the anthocyanin pigments are red when acidic and blue when alkaline. But in this case the red colour of a leaf slowly changes to green as the leaf advances towards the maturer state. That along with the change of colour the acidity might also vary was the conception under which the determinations of total acid content were undertaken.

The Table for Acid content

TABLE II

—	Different ages of leaves	Acid content
1	Youngest leaves (2 days old)	31.1 N/100
2	Very young leaves (5 days old)	30.1 N/100
3	Moderately young leaves (10-12 days old) ..	30.3 N/100
4	Leaves turning green (15-20 days old)	18.0 N/100
5	New green leaves (1 month old)	17.1 N/100
6	Old green leaves (6 months old)	10.3 N/100
7	Yellow leaves (about to fall)	10.4 N/100

In continuation with this two more experiments were carried out. In the first experiment some very young and red leaves of Eugenia all of nearly the same age were put together in a dark chamber with their petioles dipping in water. The chamber had two outlets; one of them was connected to an aspirator while the other to a bottle of fused sodium hydroxide. The total acid content of these leaves was determined after 11 hours for four days. It is surprising to note that the acid content goes on decreasing in each succeeding period. Similarly another experiment with new green leaves all of the same age was conducted. Here also a fall is noticed. The experiments are graphically represented in Fig. 1.

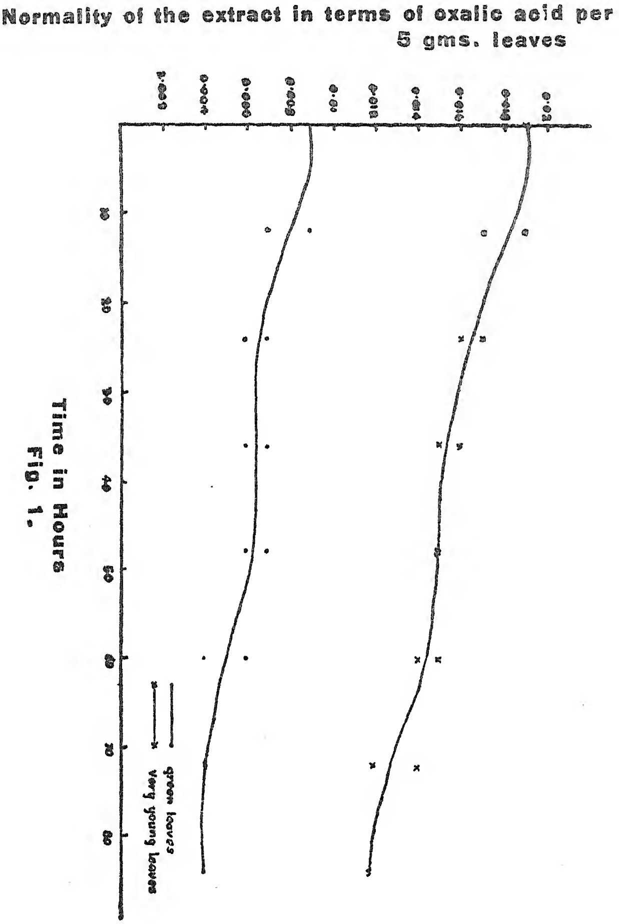

Fig. 1.

III. *Determination of catalase activity*:—

The following is the Table for Catalase activity:—

TABLE III

—	Different ages of leaves		Catalase activity in terms of O_2 evolved from H_2O_2 per 10 gms. of leaves.
1	Very young leaves	..	30 c. c. O_2
2	Moderately young leaves	..	25 c. c. O_2
3	Leaves turning green	..	22 c. c. O_2
4	New green leaves	..	20 c. c. O_2
5	Old green leaves	..	18 c. c. O_2
6	Old yellow leaves	..	18·5 c. c. O_2

IV. *Determination of monosaccharide content of Eugenia leaves of various ages:—*

The monosaccharide content of the leaves were determined as these are supposed to be the primary sugars for respiration. The following is the table for the same:—

TABLE IV

—	Different ages of leaves.	Sugar content in percentage of fresh weight.
1	Youngest leaves (2 days old)	1.43%
2	Very young leaves (5 days old)	1.34%
3	Moderately young leaves (10-12 days old) ..	0.98%
4	Leaves turning green (15-20 days old)	0.78%
5	New green leaves (one month old)	0.56%
6	Old green leaves (6 months old)	0.53%
7	Old yellow leaves (about to fall)	0.63%

The monosaccharide content of starving young and red leaves and also mature green leaves at intervals of 11 hours for four days shows that the sugar content at first falls for 20 hours thereafter it shows a slight rise which again steadily falls.

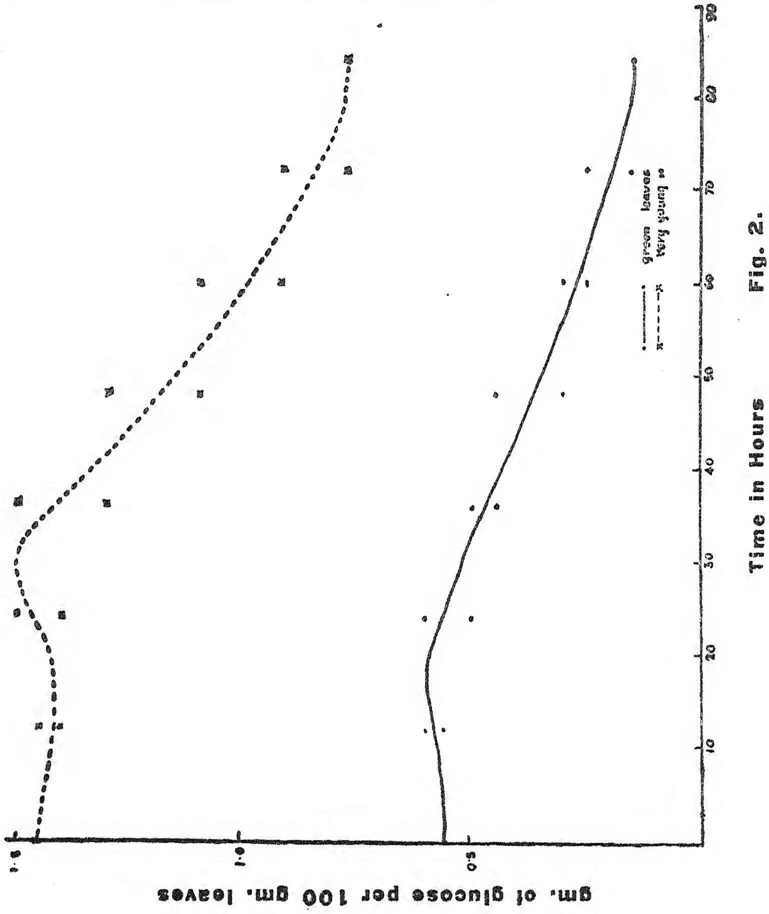

Fig. 2.

Discussion of the results

A broad analysis of the various chemical contents given in this paper may throw some further light on the nature of the respiration drift of leaves of different ages.

The CO_2 *output:—*

Fig. 3 gives graphically the trend of the CO_2 output of leaves of various ages.

All the drift of the curves shows that the rate of respiration falls off steadily with time. The rise in all the experiments occurs within 25 hours of experimentation after which the intensity begins to climb down.

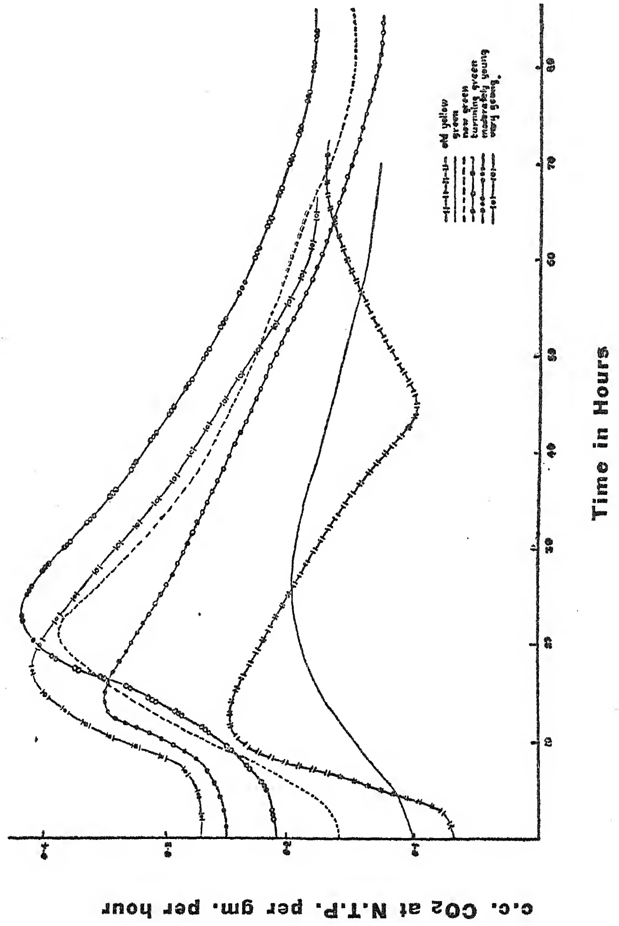

Fig. 3

The maximum intensity of respiration is different with different ages of leaves. If the total output of CO_2 in 25 hours be taken into consideration the intensity goes on decreasing with age. The actual figures calculated from the experimental data are given below:—

TABLE V

—	Ages of leaves	Total CO_2 output in 25 hrs. per gm. fresh wt.
1	Very young leaves (5 days old) ..	8.45 c.c.
2	Moderately young leaves (10-12 days old) ..	7.64 c.c.
3	Leaves turning green (15-20 days old) ..	7.72 c.c.
4	New green leaves (1 month old) ..	7.68 c.c.
5	Old green leaves (6 months old) ..	4.13 c.c.
6	Old yellow leaves (about to fall) ..	4.95 c.c.

The fall in the intensity of respiration tallies closely with the monosaccharide content of the leaves. Fig. 4 gives the graph for the monosaccharide content and the maximum intensity of respiration of leaves of various ages.

Viewing the graph one finds that the intensity of respiration is highest in the case of very young and red leaves where a maximum value of monosaccharide content is also noticed. This monosaccharide value goes on decreasing as the leaves proceed towards the maturer state. This shows that the respiration has a direct relation with the sugar content of the leaves. Again in the older stages a rise in the monosaccharide content of the leaves is noticed. It is possible that the reserve food of the leaves, before falling is changed into monosacchrides and as such is translocated away. The respiration in the old yellow leaves is found higher than in green leaves. In the case of young red leaves, the sugars are in the form of upgrade sugars while in the case of old yellow leaves they are the downgrade ones. Every process, enzymatic, etc., are in a feeble stage. When the leaves are plucked from the tree, the active anabolism, more or less becomes stationary, but since there is an increase of monosaccharides, the catabolic part or the CO_2 output increases but as soon as the monosaccharides are exhausted, the respiration falls much below the level of that of the green leaves. The after rise in the case of old yellow leaves may be attributed as a senescent rise.

The intensity of respiration does not keep up a high level attained in every case, but after some time the rate comes down. The sugar values of the leaves reveal that this fall should not have been so early. Perhaps the temperature of the bath which is as high as 35° C. has to be taken into account before the result on the basis of sugar values is interpreted. The interpretation of the temperature effect of the chamber has been dealt with previously (1).

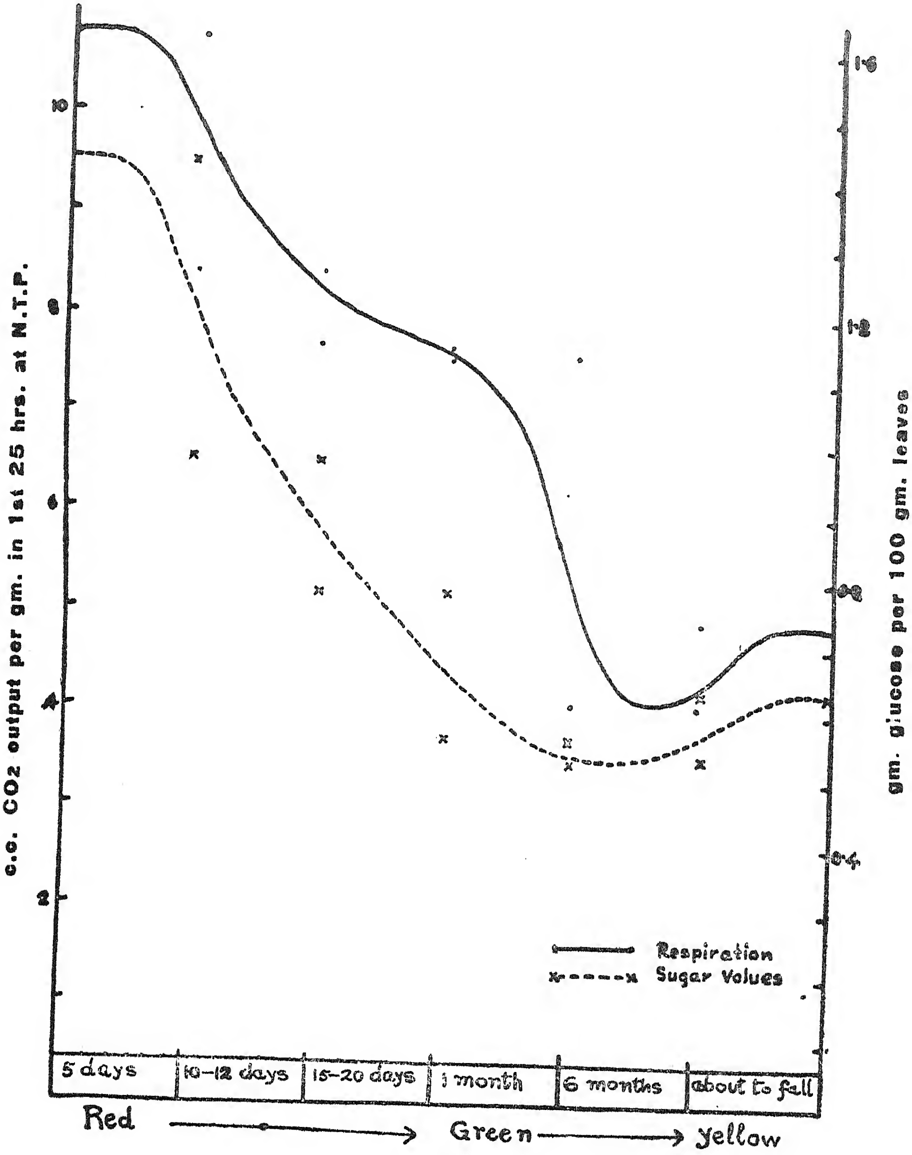

Fig. 4

The initial rate of respiration comes highest in the case of moderately young and red leaves, while the youngest leaves come next in their intensity. In the leaves turning green the intensity of respiration is much lower than in the new green leaves. The following is a chart for the initial rate and the sugar values:—

TABLE VI

—	Different ages of leaves	Initial rate of respiration in c.c. per gm.	Sugar values in percentage.
1	5 days old	.53	1.34 %
2	10-12 days old	.58	.98 %
3	15-20 days old	.44	.78 %
4	One month old	.52	.56 %
5	6 months old	.23	.53 %
6	About to fall	.30	.63 %

The initial rate of respiration varies to a wider limit with the sugar values, but the total CO_2 output in the first 25 hours tallies well with the sugar values.

Now if the total acid content and the pH values of the leaves be taken into consideration, it is found that both acidity and the total acid values decrease with the age of the leaves, except in the case of moderately young and red leaves where the total acid content is a little higher than in the very young red leaves, but for all practical purposes, the values may be considered to be the same. The youngest leaves are more acidic than the green ones. The red colour of the leaves as known to all is due to acidic anthocyanins. How this acid is neutralised or utilised in the long run of the development of the leaves is an unknown problem. Jonesco (3) however states that anthocyans are changed into flavonic glucosides in dark, which are later used up in the nutrition of the plant body. In all the experiments conducted in connection with respiration, it has been found that after 4 or 5 days the colour of the leaves changes considerably from red to a dull green; and some experiments were also done in order to know whether there is a gradual change in the total acid content of the leaves during 4 or 5 days (see Fig. 1). It has been found that the acid content goes on decreasing as the hours of experimentation proceed. This clearly shows that the acids are more or less utilised in some ways when there is an abundance of it.

The catalase content of the leaves reveal no important conclusion as to the rate of respiration, but it may be clearly seen from Table No. 3 that the catalase activity goes on decreasing with age. Ranjan and Mallik (4) from their work arrived at an important conclusion that catalase activity is more or less indirectly connected with respiration. It has been a clear fact that wherever an increase in the monosaccharide content is noticed, there is an increase in catalase activity. Catalase activity is greatly increased when the organ in question is injected with sugars. There is one important thing to note here that though there is an increase in the sugar content of the old yellow leaves, the catalase activity in these leaves is not so high as it should be; perhaps in old age the activity is lessened.

The O_2 intake of leaves of different ages

The study of the O_2 intake brings out a few of the sailent-features, *viz.*, (1) the amount of O_2 inhaled has always been found to be in excess than that of CO_2 exhaled. What is the ultimate fate of this extra amount of oxygen is an unknown problem. (2) If the amount of O_2 intake for the first 25 hours be taken into consideration, it is found that there is a gradual variation in the amount from the youngest stage to the oldest one. From Table No. 7 it is seen that the youngest leaves take in more amount of O_2 than the oldest leaves. Again from the same table, if the total difference between O_2 intake and CO_2 output in the first 25 hours and the last 25 hours be noticed, it is found that with the age of the leaves there is a gradual variation in the fixation of O_2. The youngest leaves fix more of O_2 than the oldest.

TABLE VII

—	Ages of leaves	Total O_2 intake in 1st 25 hrs.	Total O_2 intake in last 25 hrs.	Diff. in 1st 25 hrs.	Diff. in last 25 hrs.
1	5 days old ..	11.03 c.c.	6.27 c.c.	2.58 c.c.	1.82 c.c.
2	10-12 days old ..	8.68 c.c.	5.63 c.c.	1.04 c.c.	0.71 c.c.
3	15-20 days old ..	8.64 c.c.	4.22 c.c.	1.00 c.c.	0.62 c.c.
4	1 month old ..	7.93 c.c.	4.25 c.c.	0.25 c.c.	0.05 c.c.
5	6 months old ..	4.78 c.c.	3.67 c.c.	0.25 c.c.	0.04 c.c.
6	About to fall ..	4.64 c.c.	3.28 c.c.	—0.31 c.c.	0.52 c.c.

The variation in the fixation of O_2 may be due to growth and development of the organ in question. Young leaves take in more of O_2 for building up their tissues but as the leaves proceed towards the maturer state the need of O_2 goes on decreasing.

Referring to Table No. 7, it is found that the difference is much decreased in the last 25 hours of experimentation. The decrease is possibly due to two factors. In the first place the leaves are detached and no food can come to them, secondly, they cannot manufacture food being enclosed in darkness. Thus there is possibly no source of accumulation of up-grade food, hence a fall in the O_2 intake is evident.

Now, if the question of acid content be taken into consideration, it is found that the fixation of O_2 has a direct bearing with the acid content of the leaves, as will be shown in the next series.

If the total acid content and the total difference between O_2 intake and CO_2 output in 50 hours be compared, it is found that along with the acid content, the fixation of O_2 varies with the age of the leaves. The red leaves have a greater amount of acid content than that of green ones and likewise fix more of O_2. Whether the acid or the anthocyanins in the red leaves account for this higher fixation of O_2 is a disputed theory. It has been found that leaves injected with dilute doses of organic acids show a greater fixation of O_2.

How far the anthocyanins are responsible for the extra amount of O_2 intake can be known by selecting young green leaves of approximately the same age as young red leaves of *Eugenia.* One was fortunate to find such leaves in *Artocarpus integrifolia* (Kathar). *Artocarpus* leaves when they come out are perfectly green unlike the *Eugenia* leaves. For experimentation leaves of about 5 days old were taken and their CO_2 output and O_2 intake have been traced. Fig. 5 gives graphically the CO_2 output and the O_2 intake of these leaves.

Their total acid and sugar values have also been determined, but they are found to be less than those of red leaves of *Eugenia* of approximately the same age. Table No. 8 gives comparative values of the green leaves of *Artocarpus* and the red leaves of *Eugenia.*

TABLE VIII

—	Kinds of leaves.	Sugar content.	Acid values.	O_2 intake in 1st. 25 hrs.
1	Artocarpus	0.98%	20.3N/100	1.32 c.c.
2	Eugenia	1.34%	30.1 N/100	2.58 c.c.

It is found therefore in *Artocarpus* leaves in common with *Eugenia* that O_2 intake is very much greater than the CO_2 output at the start of the experiment. Towards the end this difference becomes very much less. One notable difference between *Artocarpus* and *Eugenia* is that the former has no anthocyanins while the latter has; therefore the greater O_2 intake at the start cannot be assigned to the presence of anthocyanin pigments. On the other hand it cannot be assigned to the chlorophyll either; for in the case of old yellow leaves, there is clearly a decomposition of the chlorophyll for which oxygen is needed. One should have a higher O_2 intake in those leaves but it is to the contrary. It may therefore be concluded that pigments are not largely responsible for the greater fixation of O_2.

Now turning to the acidity of the cells one finds that there is a clear similarity between the total acid content and fixation of O_2. Now, in the formation of acids from sugars certain amount of O_2 is necessarily taken up, as can be shown by the following reaction:—

$$C_6H_{12}O_6 + 3O_2 = 3C_4H_6O_5 + 3H_2O$$

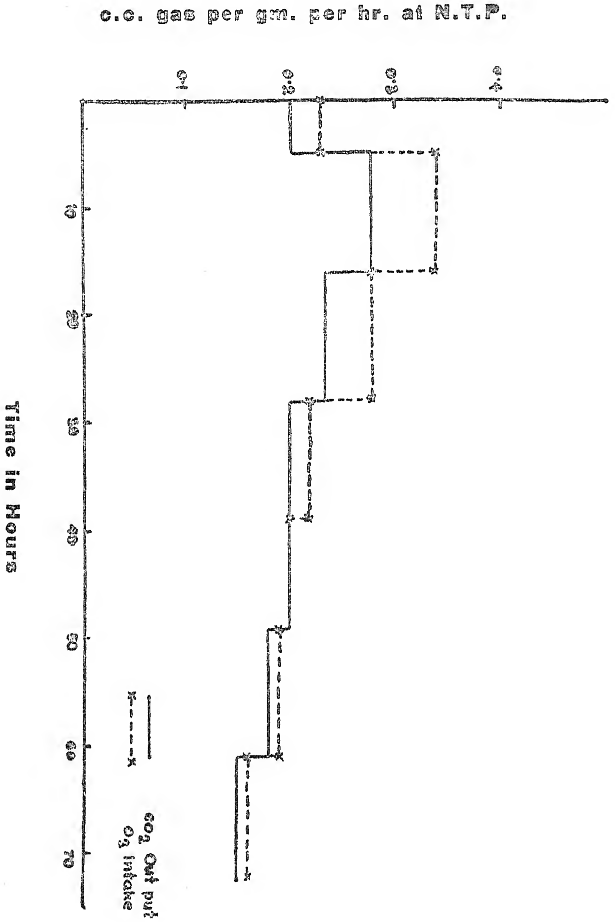

Fig. 5.

Here the Glucose is broken up into Malic acid which is found commonly in plants. On the other hand if other acids like Acetic acid are formed then O_2 is not needed, *viz.*,

$$C_6H_{12}O_6 = 3CH_3COOH$$

Granting Malic acid is formed, then greater O_2 intake which is actually the case in young leaves, is justified. But injection of acids into the leaf has shown that mere presence of excess of acids increases

O_2 intake. So that it is not the formation but the presence of acid which is responsible for greater intake of O_2. This question will further be discussed in another paper.

It has been previously mentioned that the yellow leaves contain oil globules in them and an explanation on this point has been attempted in a previous paper (1).

I wish to express my hearty thanks to Dr. S. Ranjan under whose continued guidance this work has been completed.

Summary and Conclusion

If the question of CO_2 output be now reviewed from all sides, it is found that the maximum respiration is attained between 20 and 25 hours of experimentation and then the rate of respiration begins to fall off with time. The whole drift during the period is in the typical shape of *"S"*.

The rate of respiration goes on decreasing as the leaves proceed towards maturer state. This decrease in the intensity may be due to the lowering of sugar content of the leaves at that particular age.

The acid content of the leaves goes on decreasing with age. The acid content, as it seems obvious is utilised in the economy of the whole plant itself.

The catalase content has no direct relationship with the respiration of an organ concerned, but it has a direct bearing with the sugar content of that particular organ. The Catalase content goes on decreasing like the sugar values with the age of the leaves.

Summarising the relation of O_2 intake in respiration the following points are worth noticing:—

Part of the Oxygen taken in during respiration goes for the building of the tissues in the organs concerned, so a decrease in O_2 intake is noticed as the leaves advance towards maturer state, because the process of tissue building is diminished.

The vitality of the cells decreases with starvation, thus a decrease in the CO_2 output and O_2 intake is noticed as the hours of experimentation proceed.

With the increase in acidity there is an increase in the fixation of oxygen. The younger leaves have a greater acid value and consequently there is a greater fixation of O_2.

In the case of old yellow leaves sugars are continuously being changed into oil globules thus a part of the carbon compounds are oxidised to CO_2 by the oxygen left from the oil formation. This process however decreases to a minimum value in dark.

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STRUCTURE AND DEVELOPMENT OF THE EMBRYO-SAC OF *PEMPHIS ACIDULA* FORST

BY

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A number of contributions* have already appeared from this laboratory on the embryology of the Lythraceae. The present paper deals with the structure and development of the ovule and embryo-sac of *Pemphis acidula* Forst., a maritime shrub or small tree found along the southern coast of the Indian Peninsula and Ceylon. No contribution has so far been made to the embryology of this genus.

The material used in this investigation was collected by Prof. A. C. Joshi from Krusadai Island during the month of December, 1936. It was fixed in formalin-acetic-alcohol. Sections were prepared according to the customary methods and stained with Heidenhain's Iron-alum Haematoxylin or Newton's Iodine Gentian-violet.

The Ovule

The ovules are many and borne on 3 sub-basal placentas of a 3-celled superior ovary. The septa in the ovary break off and disappear in the later stages of fruit formation and the placentation becomes free central.

The ovules are anatropous, ascending and two integumented. The micropyle is zig-zag as in most members of the Lythraceae. It is formed by both the integuments. The integuments are 2 cells thick in the early stages. By the time the ovules become anatropous, the inner and outer integuments at their micropylar free ends become 3–4 and 5–6 cells thick respectively. In the mature ovule, during the later stages, at the sides the inner integument remains two cells thick. The outer layer of the outer integument becomes two cells thick at the extreme micropylar end and remains undivided at the sides and the chalazal part. The inner layer of cells of the outer integument divides from the micropylar end downwards and becomes 5–6 cells thick.

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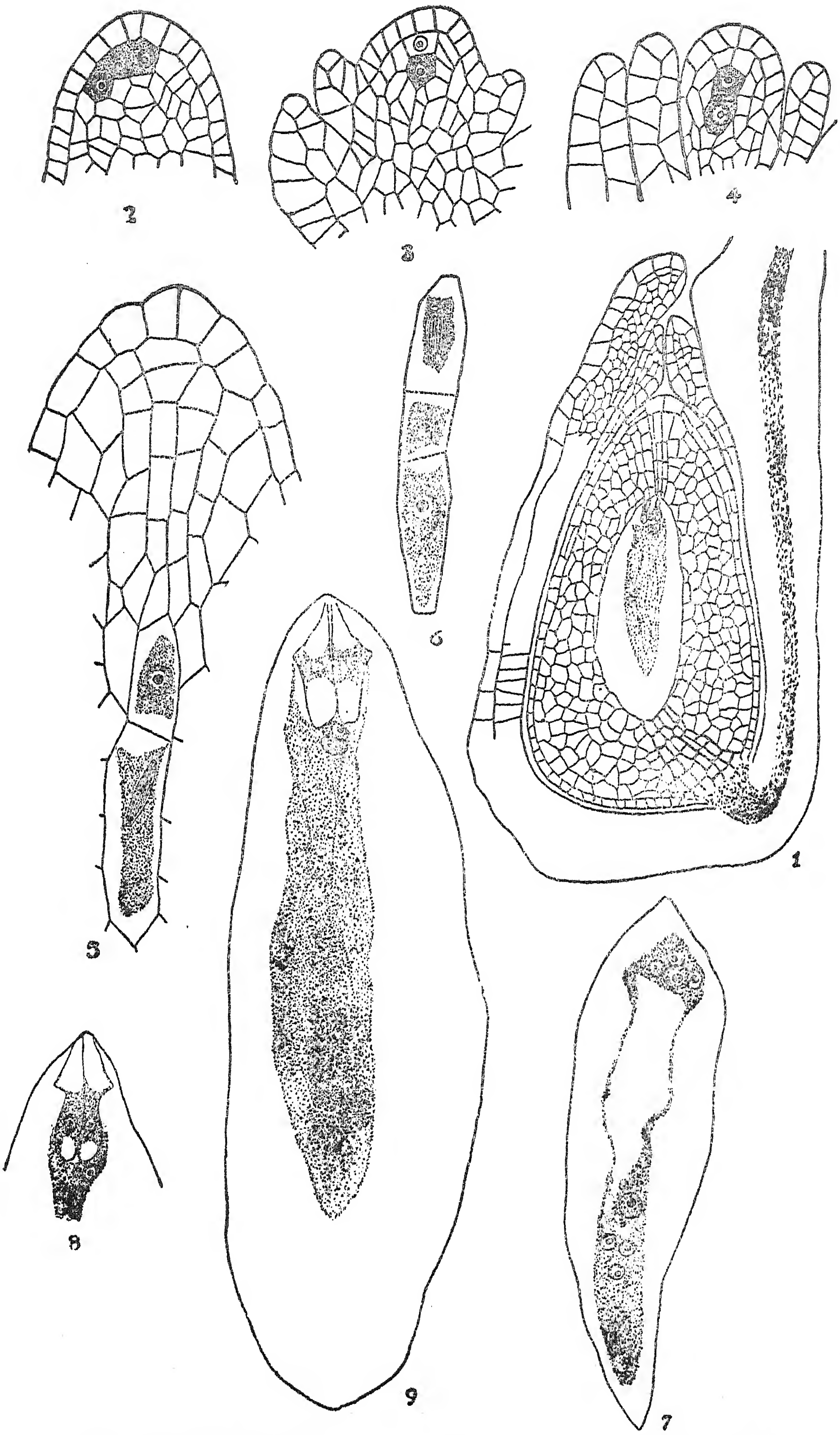
* See Joshi, A. C. and Venkateswarlu, J.—"Embryological studies in the Lythraceae—III", *Proc. Ind. Acad. Sci.*, B, 1936, III, 5, pp. 377-400 and the papers quoted there for complete literature.



Figs. 1–9, *Pemphis acidula*. Fig. 1, Longitudinal section of a fully formed ovule. Fig. 2, Primary archesporium. Fig. 3, Megaspore-mother cell and

The nucellus is moderately extensive and is 6–8 cells thick above the embryo-sac. In this plant it is further observed that some cells of the nucellar epidermis divide once periclinally specially at the micropylar part in the late stages. This feature was not noted in other investigated members of the Lythraceae. The nucellus is 6–7 cells thick on the sides of the embryo-sac and 6–10 cells thick below the embryo-sac. In the chalazal part of the nucellus a strand of conducting cells is differentiated and it connects the antipodal end of the embryo-sac with the vascular bundle of the funicle (Fig. 1).

Embryo-sac

The primary archesporium resembles that found in other Lythraceae and extends to a few cells at the tip of the nucellus (Fig. 2). These are mostly hypodermal but sub-hypodermal archesporial cells are also found. Generally only one of them develops further. Occasionally, however, two megaspore-mother cells are also met with (Fig. 4). The functional archesporial cell divides periclinally forming an outer primary parietal cell and an inner megaspore-mother cell (Fig. 3). The primary parietal cell divides first either periclinally or anticlinally. By subsequent divisions a 5–7 cells thick parietal tissue is formed. These cells, in the fully formed ovules, become considerably elongated and are thus easily distinguishable from other cells of the nucellus.

The megaspore-mother cell undergoes the usual heterotypic and homotypic divisions. In the dyad the upper cell is smaller. The homotypic division is completed much earlier in the lower dyad cell. This is shown by Figs. 4 and 5. In Fig. 4 the chalazal dyad cell is in telophase, while the nucleus of the micropylar dyad cell is still in the resting condition. In Fig. 5 the lower dyad cell has already completed its division and the nucleus of the upper one is still in telophase. In this respect it resembles *Nesaea myrtifolia, Woodfordia floribunda,* etc. The tetrad is linear. The chalazal megaspore is the functional one. After three successive free nuclear divisions an 8-nucleate embryo-sac is formed. The development of the embryo-sac thus corresponds to the normal type.

After the differentiation, the 8-nucleate embryo-sac considerably increases in size (Figs. 7 and 9), so that the mature embryo-sac is much larger than the young embryo-sac. It is pointed at the micropylar end, but broad and rounded towards the chalazal side. The egg cell has the normal structure. The synergidae are hooked and they develop a vacuole in their micropylar apex besides the chalazal vacuole. The chalazal vacuole is small in the early stages (Fig. 8), but becomes quite prominent in the synergidae of the mature embryo-sac (Fig. 9). The polar nuclei increase in size soon after their differentiation and thus become larger than the other nuclei of the embryo-sac. They fuse near the egg-apparatus before fertilisation. The antipodals degenerate early and disappear from the embryo-sac at the time of anthesis. The embryo-sac thus at the time of fertilisation is only 4-nucleate.

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primary parietal cell. Fig. 4, Two megaspore-mother cells in a row in one ovule. Figs. 5 & 6, Stages in the development of the tetrad of megaspores. Fig. 7, 8 free-nucleate embryo-sac. Fig. 8, Upper part of an embryo-sac showing young synergids and polar nuclei. Fig. 9, A 5-nucleate embryo-sac after the disappearance of the antipodals.

Fig. 1, ×157. Figs. 2-4 & 8-9, ×450. Figs. 5-7, ×800.

Summary

The ovules of *Pemphis acidula* Forst are anatropous, ascending and two integumented. In the chalazal part of their nucellus a conducting strand is differentiated. Some cells of the epidermis of the nucellus divide periclinally.

The primary archesporium is formed by a few cells. Generally only one of them is functional, but occasionally two megaspore-mother cells are also formed. The homotypic division in the chalazal dyad cell takes place earlier than in the micropylar dyad cell. The rest of the development of the embryo-sac is normal. The embryo-sac after the polar nuclei have fused is only 4-nucleate due to the early disappearance of the antipodals.

The writer, in the end, wishes to express his sincere thanks to Prof. A. C. Joshi for the material and helpful suggestions while going through the manuscript.

A NEW SPECIES OF POLYARTHRODACTYLOUS *NITELLA* WITH A REVIEW OF THE ALLIED SPECIES

BY

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In his "Notes on Indian Charophyta" Groves has recorded a single polyartrodactylous *Nitella*. The specimens referred to by Groves were collected by C. B. Clarke from Tsillong, Khasia, in 1867 and by I. H. Burkill from Amboli, Western Ghats, in 1902. On these plants Groves remarks, "Both these plants . . . agree in the main with the Australian *N. myriotricha* . . . . . There are however, some minor points of difference between the Australian plants and those from India, as well as between the Indian plants themselves." The Indian specimens could not be identified properly for want of sufficient material. Recently Pal has described a new species of the polyartrodactylous group from Burma. In October, 1926, the present author collected a few Charophytes from Shillong, among which there were some polyartrodactylous *Nitellas*. These *Nitellas* were dioecious and on careful examination, they appeared to the writer to be a new species. Some male and female plants were sent to the late Mr. Groves, who, after comparing them with the other dioecious species of the group, confirmed the determination of the writer.

The present paper deals with the description of this new species of *Nitella*, which has been named after the late Mr. Groves, the well-known authority on Charophyta. A review has been made of the allied species for the sake of finding out the relationships existing between them and the new species and a key has been prepared, which includes all the known polyartrodactylous dioecious species.

Description:

Nitella Grovesii sp. nov.

Homoeoclema (homoeophylla), arthrodactyla, pluricellulata, (polyartrodactyla) dactyli valde elongati, 2-3-cellulati, gymnocephala, dioecia.

Dioecious:

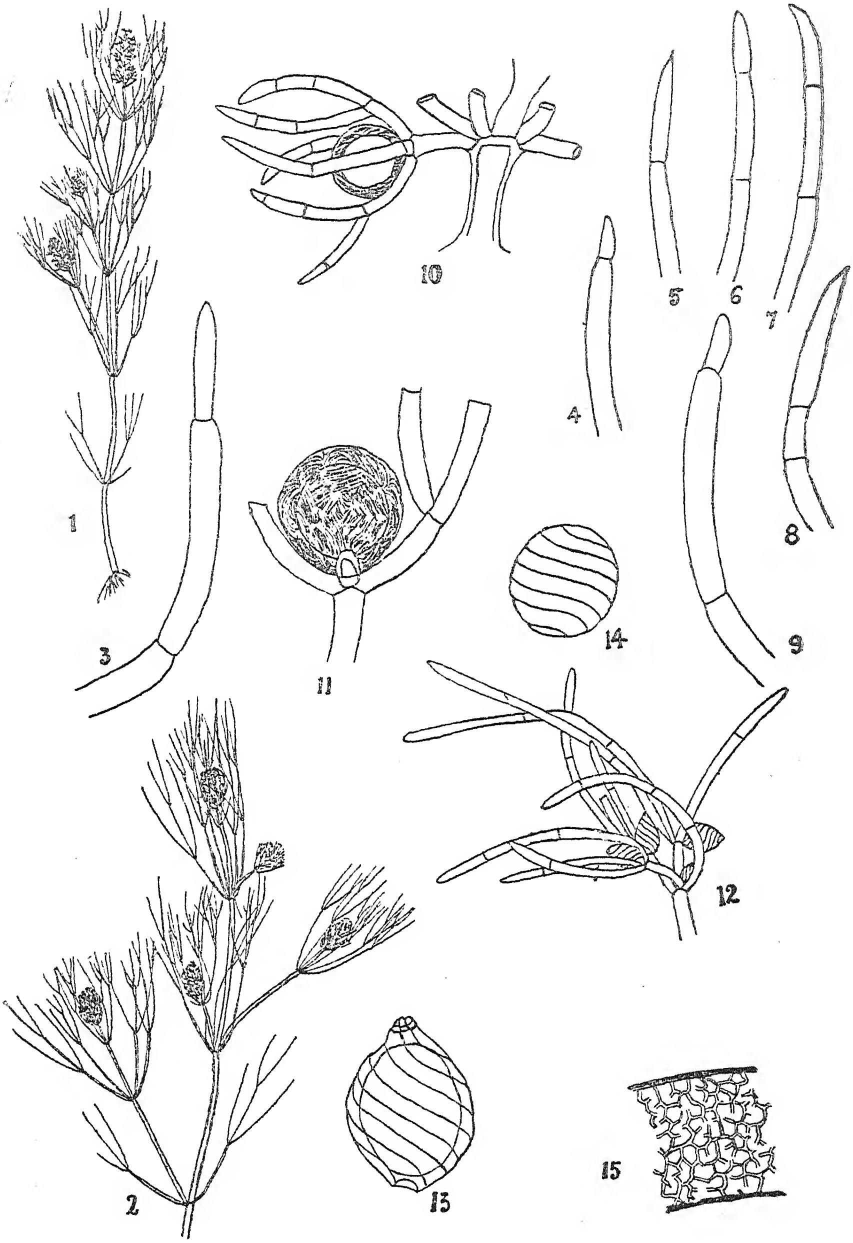
Male plant.—Stem 525-555μ thick; not incrusted. Internodes shorter than the branchlets. Branchlets of the sterile whorls 6-7 in a whorl; 1¼ to about 2 cm. in length, once or twice furcate. Primary rays unequal, half or nearly half of the entire branchlets; secondary rays 2-4, as long as or longer than the primary rays; one or two of them again furcate into two terminal rays. Fructifications are always found in axillary and terminal loose heads (which may be sometimes very slightly enclosed in mucus). Branchlets of the fertile whorls 5-7 in a whorl, very short, not more than 3 mm. in length; once or twice furcate. Primary rays very short, one-fifth to one-third of the entire branchlet. Secondary rays 3-4; one or two of them again furcate into 2-3 terminal rays. Dactyls 2-3-celled, very rarely 4-celled; ultimate cells 45-65μ thick; very variable in length; usually long and allantoid, sometimes short. Antheridia at the first or second furcations of the branchlets; 420-435μ in diameter.

Female plant.—Shorter but somewhat stouter than the male plants. Branchlets of the sterile whorls 6-8; 2-3 cm. in length, once or twice forked. Primary ray nearly 1/3 the length of the entire branchlet; secondary rays 2-4; one or two of them again furcate into 2-3 ultimate rays. Fertile whorls in loose heads; branchlets short, usually 6 in number, up to 1 cm. in length; once or twice furcate. Primary ray very short; secondary rays 2-4, long when undivided and very short, even shorter than the primary ray when divided; some of them are again forked into 2-3 terminal rays. Oogonia solitary in the first and second furcations of the branchlets; 375-400μ long, (including coronula), 285-300μ broad; spiral cells show 8-9 convolutions. Coronula erect, short and persistent. Oospore 240-255μ long, 210-225μ broad, showing about 7 low ridges; light to dark brown. Membrane imperfectly reticulate.

Collected from a shallow ditch near Elephant Falls, Shillong, Assam. October, 1926.

It is a moderately stout graceful plant with the branchlets 1-2-times furcate. The ultimate cells of the dactyls are usually as thick as the penultimate ones, though shorter and thinner ultimate cells on very long lower ones have been found in some cases.

N. Grovesii resembles *N. myriotricha* A. Br. and *N. superba* Pal in having the ultimate cells of most of the dactyls long and allantoid and as thick or nearly as thick as the penultimate ones. But both of them can be differentiated from this species as follows: *N. myriotricha* by the branchlets 3-4-times furcate, by the ultimate cells of dactyls being extremely thin (20μ thick) and by the fruiting whorls being enveloped in a dense mass of mucus. *N. superba* by the branchlets 2-4-times furcate, by the fruiting heads enveloped in mucus and by the smaller oogonia (300-350μ long, 210-240μ broad). It seems that the nearest relations of *N. Grovesii* are *N. tasmanica* A. Br. and *N. gelatinosa* A. Br., the branchlets of which are 1-2-times furcate. It resembles *N. tasmanica* also in other points viz., in



Figs. 1—15. *Nitella Grovesii* sp. nov.

Fig. 1. Male plant (about natural size). Fig. 2. Female plant (about natural size). Figs. 3-9. Dactyls. × 25. Fig. 10. Portion of a fertile whorl of a male plant, showing one complete branchlet. × 15. Fig. 11. Branchlet node with an antheridium. × 25. Fig. 12. A fertile branchlet of the female plant. × 10. Fig. 13. Oogonium. × 55. Fig. 14. Oospore. × 55. Fig. 15. Portion of oospore membrane showing decoration.

having the fruiting whorls in comparatively loose heads, in the structure of the oospore and the irregularly arranged reticulations of the oospore membrane. But both *N. tasmanica* and *N. gelatinosa* differ from it by the following characters: *N. tasmanica* by the 3-4-(sometimes even 5-) celled dactyls, by the ultimate cells of dactyls being tapering and acute and by the very gelatinous fruiting heads. *N. gelatinosa* by the fruiting whorls in very small dense heads enveloped in mucus, by the 2-4-celled dactyls, and by the ultimate cells of dactyls being often very short, conical and pointed (mucro). The ultimate cells of dactyls of all the other dioecious species of this section are usually short and always conical and acute, the dactyls being gradually tapering; by this character alone all of them are separated from *N. Grovesii.*

A key to all the polyartrodactylous dioecious *Nitellas* may be given as follows:—

Key to the dioecious species

Dactyls 2-6 celled. Polyarthrodactylae (Arthrodactylae, Pluricellulatae)

Dioecious:

I. Ultimate cells of dactyls usually short, and always conical and acute; dactyls often gradually tapering.

A Sporangia produced at the base of the whorls............ *N. plumosa* A. Br.

AA Sporangia not produced at the base of the whorls.

B Fruiting whorls not forming dense heads.

Branchlets (1-) 2-3-times furcate; rays at each forking 3-4; end segments short with attenuated cells; antheridia 550μ in diameter........................*N. diffusa* A. Br.

CC Branchlets 2-3 times furcate, rays at each forking 4-5; end segments long; antheridia 325-410μ in diameter. *N. Dixonii* Groves.

BB Fruiting whorls more or less forming dense heads.

D Fertile and sterile branchlets 3-4 times furcate. *N. huillensis* A. Br.

DD Sterile branchlets often simple, fertile ones 1-2 times furcate.

E Oospore 300-380μ long.

F Oogonia solitary or aggregate; ridges of oospores very much pronounced; membrane decorated with tubercles. *N. cristata* A. Br.

FF Oogonia aggregate; ridges of oospores not much pronounced; membrane finely granulate with large irregular more or less elongated projections. *N. struthioptila* Gr. & St.

EE Oospore 200-270μ long.

G Fruiting whorls forming comparatively loose heads. *N. tasmanica* A. Br.

GG Fruiting whorls forming small dense very gelatinous heads; ultimate cells of dactyls very variable. *N. gelatinosa* A. Br.

EEE Oospore 160-180μ long. *N. polycephala* A. Br.

DDD Branchlets once furcate; fruiting heads enveloped in mucus. *N. arechavaletae* Speg.

II. Ultimate cells of dactyls nearly as thick as the penultimate ones, usually elongated and allantoid (if the ultimate cells are short and thinner than the penultimate ones, then there must many others in the same or different branchlets, which are nearly as thick as the penultimate ones). Dactyls not attenuated and usually 2-3 celled.

A Fertile and sterile whorls 2-5 times furcate; fertile whorls enveloped in mucus.

B Oogonia 370-390μ long, 270-280μ broad; branchlets 3-5 times furcate......................*N. myriotricha* A. Br.

BB Oogonia 300-350μ long, 210-240μ broad branchlets 2-4 times furcate............................*N. superba* Pal.*

AA Fertile and sterile whorls 1-2 times furcate.

C Fertile whorls in very small dense heads, enveloped in mucus; Dactyls 3-4 (sometimes even 5-) celled............. *N. gelatinosa* A. Br.

CC Fertile whorls in loose heads, not enveloped in mucus; dactyls 2-3 celled................*N. Grovesii* Kundu.

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[*] Mr. Pal has founded this new species "*N. superba*" on some plants from Burma, and says (Burmese Charophyta, page 69) that this is evidently the species referred to by Groves (1924) as "Nitella sp., *N. myriotricha* Kütz. prox." But unfortunately Mr. Pal does not explain how his plant differs from *N. myriotricha* Kütz. What I have gathered from his descriptions, is that his species *N. superba* differs from *N. myriotricha* Kütz. only in the size of the oogonia. I had some correspondence with Mr. G. O. Allen on *N. superba* and *N. Grovesii.* On *N. superba* Mr. Allen writes to say, "I consider it most unfortunate that Mr. Pal should not have obtained ripe fruit before publishing his *N. superba,* as the decoration of the oospore membrane is nowadays regarded as so highly important a character to differentiate species, and now it can never be known *for certain* what that decoration is in the case of *N. superba.* Mr. Groves on several occasions refrained from publishing 'new species' when he had not got ripe oospores. One instance is Mr. Groves's No. 4 in his Notes on Indian Charophyta (Linn. Soc. Journ., XLVI, 1924, p. 365). This was named by Pal as *N. Annandalei* and the same difficulty arises as in the case of his *N. superba.*"

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THE ZYGNEMOIDEAE OF THE UNITED PROVINCES, INDIA—I*

BY

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No member of Conjugales has yet been described from the United Provinces. It is therefore desired to record these algae in a series of papers. The present communication deals with some of the Zygnemoideae, collected from Benares and its environs, during the last two years. Four forms collected from Chakia, one from Chunar and six from Sarnath have also been included. In all forty-two forms have been recorded, and out of these, three species, six varieties and twenty-three forms are new.

SYSTEMATIC ENUMERATION OF THE SPECIES OBSERVED.

(A) Zygnemaceae

Genus *Zygnema* Agardh

1. *Zygnema cyanosporum* Cleve. Czurda in Pascher's Süsswasser-flora, Mitteleuropas, Heft 9, 1932, p. 106, Fig. 104.

Lat. cell., 21–23 μ; long. cell., 37–70 μ; crass. zygosp., 36–40 μ.

Habitat:—In a rain-water pool, along with *Spirogyra plena* forma.

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*From the Department of Botany, Benares Hindu University.

2. *Zygnema gangeticum* sp. nov. (Fig. 1, *A–C*).

Vegetative cells upto six times as long as broad; filaments with a faint, hyaline and regular mucilaginous envelope; conjugation scalariform and lateral; zygospore formation in the conjugation canal. Zygospores ellipsoidal to almost spherical; exospore thin, smooth and hyaline; mesospore thin, smooth and yellowish-brown.

Lat. cell., 16–20 μ; long. cell., 60–100 μ; crass. zygosp. spheric., 30–38 μ; long. zygosp. ellipsoid., 36–43 μ.

Habitat:—In puddles on the sides of the river Ganges, along with *Mougeotia tenuis, Spirogyra Weberi* forma, *S. flavescens, S. decimina* and also sterile filaments of *Spirogyra* and *Zygnema.*

The alga belongs to the Section 'Pectinata' of the genus on account of the formation of zygospores in the conjugation canal (Czurda, *op. cit.,* 1932, p. 99). The alga is comparable to *Zygnema Carteri* Czurda and *Z. pseudopectinatum* Czurda on account of the conjugation being both scalariform and lateral, formation of zygospores in the conjugation canal and the spherical zygospores. It further agrees with the former species in the dimensions of the zygospores and with the latter species in the zygospores being also ellipsoidal. But it differs from both in the possession of a smooth mesospore. It further differs from the former species in having broader cells and having also ellipsoidal zygospores and from the latter in having narrower cells and bigger zygospores.

3. *Zygnema sphaerica* Misra. Misra, Zygnemaceae of Kashmir—I, *Proc. Ind. Acad. Sci.,* B, Vol. V, No. III, 1937, Fig. 1, *C.*

Forma *megaspora* form. nov. (Fig. 1, *D*).

Lat. cell., 26–33 μ, average 28 μ; long. cell., 23–90 μ, average 60–66 μ; crass. zygosp. spheric., 26–50 μ, average 33–38 μ; long. zygosp. subspheric., 43–50 μ.

Habitat:—In a pond.

The form differs from the type in having slightly broader cells and much bigger zygospores. The diameter of the zygospores is commonly greater than the breadth of the gametangia and the former therefore extend into the conjugation canal.

Forma (Fig. 1, *E*).

Lat. cell., 30–34 μ; long. cell., 30–100 μ; crass. zygosp. spheric., 33–36 (–40) μ; long. zygosp. subspheric., 43–46 μ.

Habitat:—In a road-side channel.

The form differs from the type in the presence of broader cells and bigger zygospores and from the above form in the cells being slightly broader and the zygospores smaller.

4. *Zygnema normani* Taft. Transeau, Tiffany, Taft and Li, New Species of Zygnemataceae, *Trans. Micro. Soc.,* Vol. LIII, No. 3, 1934, Pl. XVII, Fig. 12.

Var. *lamellata* var. nov. (Fig. 2, *A* & *B*).

Conjugation scalariform; zygospore formation in one of the gametangia; fructifying cells unswollen. Zygospores globose to sub-globose; exospore thin, smooth and hyaline; mesospore thick, lamellated, yellowish-brown upto dark brown with rather shallow and broad scrobiculations.

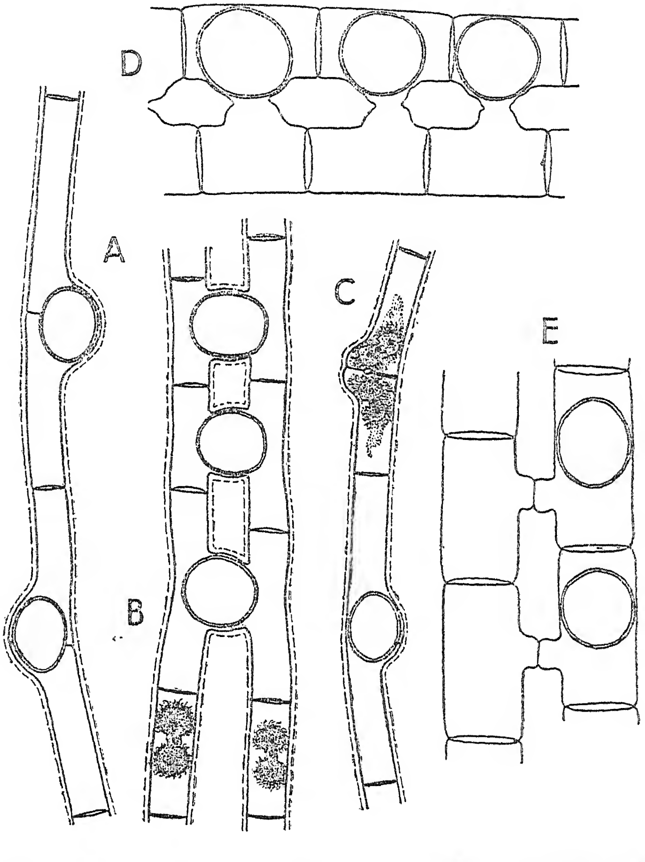

Fig. 1. *A–C*—Portions of conjugating filaments of *Zygnema gangeticum* sp. nov. with zygospores; *D* and *E*—the same of *Zygnema sphaerica* Misra forma *megaspora* form. nov., and *forma* respectively.

A–C ×240; *D* and *E* ×285.

Lat. cell., 23–26 μ; long. cell., 30–97 μ; diam. zygosp., 26–36 (–39) μ; scrobiculations, 5 μ broad and 1–3 μ apart.

Habitat:—In a road-side channel along with *Sphaeroplea annulina, Hydrodictyon reticulatum* and *Spirogyra Spreeiana* var. *crassa.*

The variety agrees with the type in the scalariform conjugation, globose to sub-globose zygospores provided with a thin, smooth and hyaline exospore, yellowish-brown and scrobiculated mesospore and situated in one of the gametangia, which is inflated towards the conjugating side, but differs from the same in the presence of smaller zygospores provided with a lamellated mesospore* and in the scrobiculations being broader and fewer.

5. *Zygnema cylindrosporum* Czurda. Czurda, *op. cit.,* 1932, p. 123, Fig. 126.

Var. *crassa* var. nov. (Fig. 2, *C* & *D*).

Conjugation scalariform; zygospore formation in one of the gametangia; fructifying cells unswollen. Zygospores spherical or almost spherical; exospore thin, smooth and hyaline; mesospore thick, dark-brown when immature and yellowish-brown at maturity, with numerous, small, widely set and sharp scrobiculations.

Lat. cell., 33–38μ ; long. cell., 50–104 μ; crass. zygosp. spheric., 30–36 μ; long. zygosp. subspheric., 30–43 μ; scrobiculations 1–2 μ broad and 3–7 μ apart.

Habitat:—In a rain-water pool.

The variety agrees with the type in the scalariform conjugation, unswollen fructifying cells and spherical or sub-spherical zygospores with a thin, smooth and hyaline exospore and a thick, yellowish-brown to brown scrobiculated mesospore, but differs in the presence of broader filaments, always having spherical or sub-spherical (but never cylindrical) zygospores, and the scrobiculations on the mesospore being numerous, small, widely set and sharp.

Genus *Spirogyra* Link.

6. *Spirogyra Spreeiana* Rabenhorst. Czurda, *op. cit.,* 1932, p. 149, Fig. 147.

Var. *crassa* var. nov. (Fig. 2, *E* & *F*).

Vegetative cells, 3–8 times as long as broad; end-walls replicate; chloroplast one. Conjugation scalariform and rather rarely lateral; fructifying cells swollen. Zygospores ellipsoidal; exospore thin, smooth and hyaline; mesospore thick, smooth and yellowish-brown; endospore indistinct.

Lat. cell., 20–23 μ; long. cell., 60–170 μ; crass. zygosp. 26–30 μ; long. zygosp., 46–74 μ; crass. cell. fructif., 26–30 μ.

Habitat:—In a road-side channel along with *Sphaeroplea annulina, Hydrodictyon reticulatum* and *Zygnema normani* Taft var. *lamellata* var. nov.

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*As the author of *Zygnema normani* has not given any idea of the thickness of the mesospore, a comparison of the same with that of the Benares form is therefore not possible.

The variety agrees with the type in having replicate end-walls, one chloroplast, swollen fructifying cells and ellipsoidal zygospores with thin, smooth and hyaline exospore and thick, smooth and yellowish-brown mesospore, but differs in the possession of broader cells and narrower zygospores, fructifying cells being slightly less swollen and the conjugation canal being formed by both the gametangia.

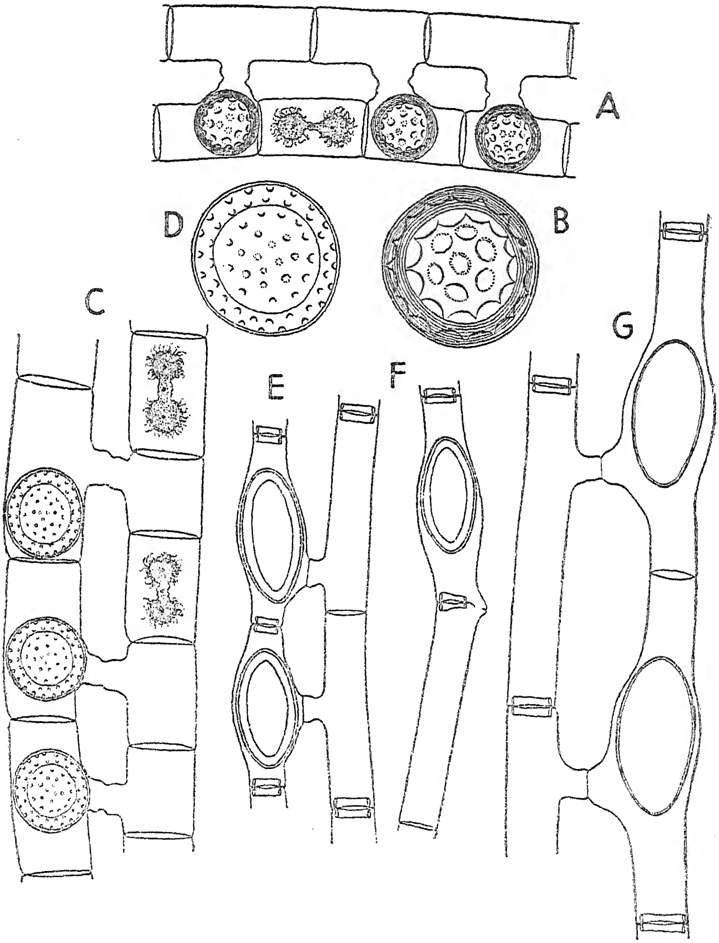

Fig. 2. *A*—Conjugating filaments with zygospores and *B*—a highly magnified zygospore showing the surface sculpture of *Zygnema normani* Taft var. *lamellata* var. nov.; *C* & *D*—the same of *Zygnema cylindrosporum* Czurda var. *crassa* var. nov.; *E* & *F*—conjugating filaments of *Spirogyra Spreciana* Rabenhorst var. *crassa* var. nov. with zygospores; and *G*—the same of *Spirogyra Weberi* (Kütz.) Czurda forma *inflata* form. nov.

A, C, E and *F* ×285; *B* and *D* ×585; *G* ×240.

7. *Spirogyra Weberi* (Kütz.) Czurda. Czurda, *op. cit.*, 1932, p. 154, Fig. 153.

Lat. cell., 26–30 μ; long. cell., 130–200 μ; crass. zygosp., 26–36 μ; long. zygosp., 46–70 μ; crass. cell. fructif., 36 μ.

Habitat:—In a rain-water pool, Chakia, Benares State, along with a sterile species of *Spirogyra*.

Forma.

Lat. cell., 16–18 μ; long. cell., 165–200 μ; crass. zygosp., 26–30 μ; long. zygosp., 56–62 μ; crass. cell. fructif., 26–30 μ; long. cell. fructif., 170–200 μ.

Habitat:—In puddles on the sides of the river Ganges along with *Zygnema gangeticum* sp. nov., *Spirogyra flavescens, S. decimina, Mougeotia tenuis* and also sterile filaments of *Spirogyra* and *Zygnema.*

This form differs from the type in the presence of much narrower cells.

Forma *inflata* form. nov. (Fig. 2, *G*).

Lat. cell., 23–26 μ; long. cell., 150–178 μ; crass. zygosp., 30–36 μ; long. zygosp., 69–83 μ; crass. cell. fructif., 40–50 μ.

Habitat:—In a rain-water pool, Sarnath, along with *Spirogyra neglecta, S. setiformis* var. *maxima* var. nov., *S. paradoxa* sp. nov. and sterile filaments of *Oedogonium* and *Zygnema.*

The form differs from the type in having narrower cells and longer zygospores and the fructifying cells being more inflated.

8. *Spirogyra Chuniae* Jao. Jao, New Zygnemataceae collected in China, *American Journal of Botany,* Vol. 23, No. 1, 1936, p. 54, Figs. 2 & 3.

Forma (Fig. 3, *A–C*).

Lat. cell., 30–33 μ; long. cell., 75–194 μ; crass. zygosp., 36–43 μ; long. zygosp., 69–85 μ; crass. cell. fructif., 46–56 μ.

Habitat:—In a rain-water pool along with *Hydrodictyon reticulatum, Calothrix brevissima,* and sterile filaments of *Spirogyra* and *Oedogonium.*

The form differs from the type in the conjugation being mostly lateral and only rarely scalariform.

9. *Spirogyra flavescens* (Hass.) Kütz. Borge and Pascher in Pascher's Süsswasser-flora Deutschlands Österreichs und der schweiz, Heft 9, 1913, p. 20, Fig. 15.

Lat. cell., 11–14 μ; long. cell., 43–102 μ; crass. zygosp., 19–23 μ; long. zygosp., 36–40 μ; crass. cell. fructif., 26–28 μ.

Habitat:—In puddles on the sides of the river Ganges, along with *Spirogyra decimina, S. Weberi forma, Zygnema gangeticum* sp. nov., *Mougeotia tenuis* and also sterile filaments of *Spirogyra* and *Zygnema.*

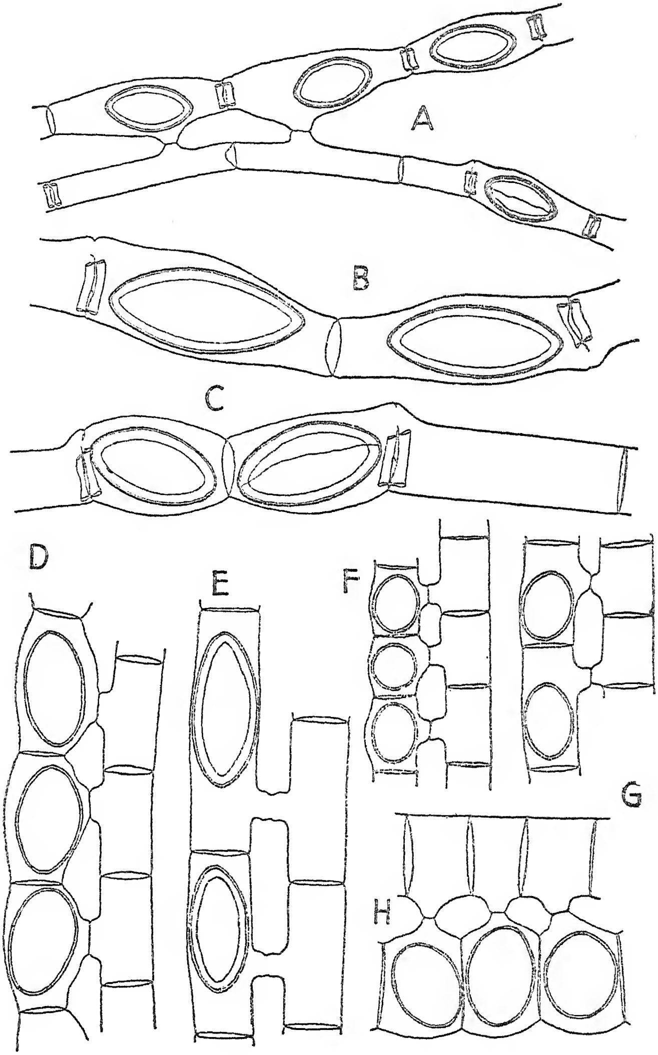

Fig. 3. *A–C*—Conjugating filaments of *Spirogyra Chuniae* Jao *forma* with zygospores; *D*—the same of *Spirogyra olivascens* Rabenhorst; *E*—the same of *Spirogyra Juergensii* Kützing; *F* & *G*—the same of *Spirogyra dubia* Kütz. *forma; H*—the same of *Spirogyra ternata* Ripart forma *maxima* form. nov.

A and *F–H* ×130; *B–E* ×285.

10. *Spirogyra olivascens* Rabenhorst. Czurda, *op. cit.*, 1932, p. 168. (Fig. 3, *D*).

Vegetative filaments upto three times as long as broad; end-walls plane; chloroplast one. Conjugation scalariform; fructifying cells swollen. Zygospores ellipsoidal with rounded ends; exospore thin, smooth and hyaline; mesospore thick, smooth and yellowish-brown.

Lat. cell., 27–33 μ; long. cell., 80–110 μ; crass. zygosp., 33–40 μ; long. zygosp., 52–75 μ; crass. cell. fructif., 40–44 μ.

Habitat:—In a pond near the temple at Sarnath, along with sterile filaments of *Spirogyra* and *Oedogonium*.

The present alga closely agrees with the description given for the type. No original figure of the type was consulted, but the figure of *Spirogyra subsalina* Cedercreutz (Cedercreutz, Finnlandische Zygnemalen, *Acta Societatis Pro fauna et flora fennica*, 55, No. 2, 1924), a form taken to be a synonym of *Spirogyra olivascens* by Czurda,* has been consulted and there is in all essentials a close agreement between the Finnish form and the Benares alga except that the conjugation canal in the latter form is formed by both the gametangia.

11. *Spirogyra Juergensii* Kützing. Borge and Pascher, *op. cit.*, 1913, p. 22, Fig. 23. (Fig. 3, *E*).

Vegetative cells upto thrice as long as broad; end-walls plane; chloroplast one. Conjugation scalariform; conjugation canal formed by both the gametangia; fructifying cells unswollen or sometimes slightly distended by the zygospores. Zygospores ellipsoidal; exospore thin, smooth and hyaline; mesospore thick, smooth and yellowish-brown; endospore indistinct.

Lat. cell., 26–30 μ; long. cell., 42–115 μ; crass. zygosp., 30–32 μ; long. zygosp., 50–66 μ.

Habitat:—In a rain-water pool along with two species of *Oedogonium*.

12. *Spirogyra decimina* (Mull.) Czurda. Czurda, *op. cit.*, 1932, p. 176, Fig. 181.

Lat. cell., 28–33 μ; long. cell., 66–197 μ; crass. zygosp., 28–36 μ; long. zygosp., 46–76 μ.

Habitat:—In puddles on the sides of the river Ganges along with *Zygnema gangeticum* sp. nov., *Mougeotia tenuis, Spirogyra Weberi* forma, *S. flavescens* and sterile species of *Spirogyra* and *Zygnema*.

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* Czurda, *op. cit.*, 1932, p. 168.

Forma.

Lat. cell., 33–36 μ; long. cell., 80–200 μ; crass. zygosp., 33–38 μ; long. zygosp., 41–69 μ.

Habitat:—In a rain-water pool, Chakia, Benares State, along with *Bulbochaete* sp., *Oedogonium* sp. and a sterile species of *Spirogyra.*

The form differs from the type in the slightly broader filaments.

13. *Spirogyra dubia* Kützing. Czurda, *op. cit.,* 1932, p. 188.

Forma (Fig. 3, *F* & *G*).

Vegetative cells as long as or slightly longer than broad; end-walls plane; chloroplasts 2–3. Conjugation scalariform; fructifying cells swollen commonly on one or occasionally on both sides and sometimes not swollen at all. Zygospores ellipsoidal to spherical; exospore thin, smooth and hyaline; mesospore thin, smooth and brown; endospore indistinct.

Lat. cell., 40–50 μ; long. cell., 52–66 μ; crass. zygosp., 43–52 μ; long. zygosp., 60–69 (–85) μ; crass. cell. fructif., upto 66 μ.

Habitat:—In a pool near Chunar, Benares State, along with a sterile species of *Spirogyra.*

The form agrees with the type in the thickness of the filaments, plane end-walls, 2–3 chloroplasts, scalariform conjugation, swollen fructifying cells, ellipsoidal zygospores with a smooth brown mesospore but differs from the same in the fructifying cells being commonly swollen on one side only and occasionally on both sides and sometimes not swollen at all. It further differs in having shorter zygospores, that are also spherical, with a thin mesospore.

14. *Spirogyra ternata* Ripart. Czurda, *op. cit.,* 1932, p. 189, Fig. 197 A and B.

Forma *maxima* form. nov. (Fig. 3, *H*).

Lat. cell., 85–89 μ; long. cell., 33–43 μ; crass. zygosp., 62–92 μ; long. zygosp., 82–95 μ; crass. cell. fructif., 100–112 μ.

Habitat:—In a pond along with *Zygnema cylindrosporum* var. *crassa* var. nov.

The form differs from the type in the chloroplasts being 2–4 and having much broader cells and zygospores with a thin mesospore.

Forma (Fig. 4, *A*).

Lat. cell., 58–65 μ; long. cell., 45–66 (–130) μ; crass. zygosp., 50–75 μ, average 55–66 μ; long. zygop., 66–93 μ; crass. cell. fructif., 72–82 μ.

Habitat:—In a pond.

The form differs from the type in the fructifying cells being less swollen and the zygospores* being frequently longer, sometimes with pointed ends.

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* Ripart's figures of the type show globose zygospores as well, but no mention is made about them in the description.

15. *Spirogyra Fullebornei* Schmidle. Czurda, *op. cit.,* 1932, p. 190.

Forma *crassa* form. nov. (Fig. 4, *B*).

Vegetative cells upto three times as long as broad; end-walls plane; chloroplasts 2–4. Conjugation scalariform; fructifying cells unswollen. Zygospores ellipsoidal and rarely sub-spherical; exospore thin, smooth and hyaline; mesospore thin, smooth and yellowish-brown.

Lat. cell., 46–51 μ; long. cell., 50–165 μ; crass. zygosp. ellipsoid, 48–50 μ; long. zygosp. ellipsoid., 85–93 μ, average 60–82 μ; crass. zygosp. subspheric., 43–55 μ.

Habitat:—In a rain-water pond.

The form agrees with the type in the possession of plane end-walls, number of chloroplasts, scalariform conjugation, unswollen fructifying cells, ellipsoidal zygospores with a thin, smooth and hyaline exospore, yellowish-brown and smooth mesospore but differs in the presence of broader cells and zygospores that may in rare cases be sub-spherical and occasionally longer than in the type with a thin mesospore.

Forma.

Lat. cell., 46–50 μ; long. cell., 60–115 μ; crass. zygosp. ellipsoid., 46–50 μ; long. zygosp. ellipsoid., 63–73 μ; crass. zygosp. subspheric., 43–50 μ.

Habitat:—In a rain-water pond.

This form almost agrees with the previous form except that the ellipsoidal and subspherical zygospores are equally common.

16. *Spirogyra columbiana* Czurda. Czurda, *op. cit.,* 1932, p. 190, Fig. 199.

Forma (Fig. 4, *C* and *D*).

Lat. cell., 48–53 μ; long. cell., 76–170 μ; crass. zygosp. commonly 50 μ, and rarely upto 60 μ; long. zygosp., 59–85 (–115) μ, average 58–75 μ; crass. zygosp. sub-spheric., 50–55 μ.

Habitat:—In a rain-water pool.

The form agrees with the type in all respects except that the zygospores are of variable shapes and occasionally longer.

17. *Spirogyra neglecta* (Hassall) Kützing. Czurda, *op. cit.,* 1932, p. 191, Fig. 200.

Lat. cell., 60–66 μ; long. cell., 73–151 μ; crass. zygosp., 58–66 μ; long. zygosp., 95–106 μ.

Habitat:—In a rain-water pool, Sarnath, along with *Spirogyra Weberi* forma, *S. setiformis* var. *maxima* var. nov., *S. paradoxa* sp. nov., and sterile filaments of *Oedogonium* and *Zygnema*.

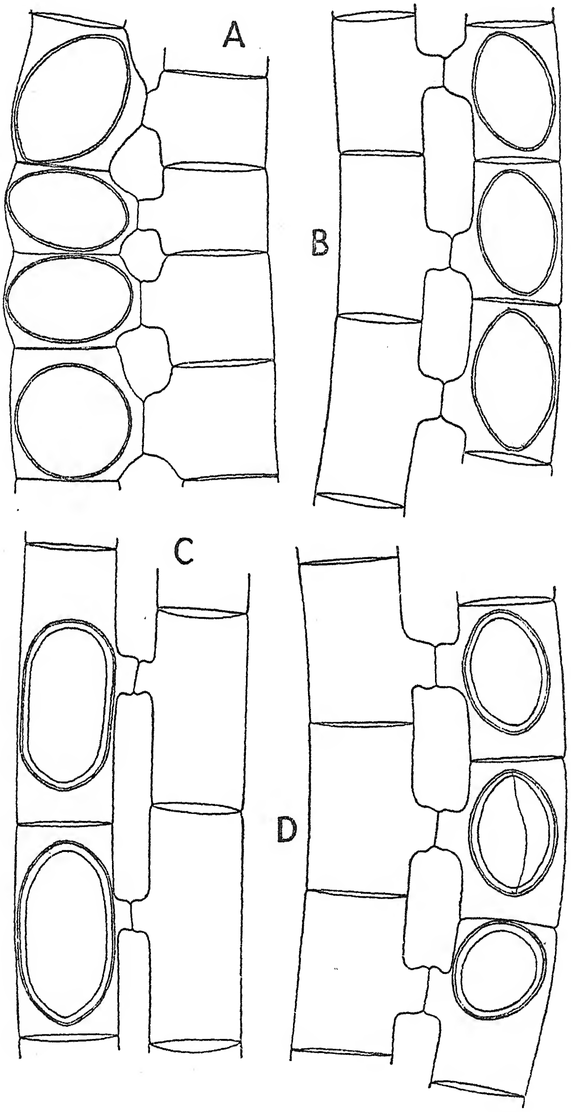

Fig. 4. *A*—Conjugating filaments of *Spirogyra ternata* Ripart *forma* with zygospores; *B*—the same of *Spirogyra Fulleborni* Schmidle *forma; C* and *D*—the same of *Spirogyra columbiana* Czurda *forma.* All ×240.

Forma *tenuis* form. nov. (Fig. 5, *A*).

Lat. cell., 56–60 (–63) μ; long. cell., 52–130 μ; crass. zygosp., 52–69 μ; long. zygosp., (72–) 90–132 μ.

Habitat:—In a road-side channel, Benares Hindu University grounds.

The form differs from the type in having slightly narrower cells and frequently longer zygospores with a thin mesospore.

Forma (Fig. 5, *B*).

Lat. cell., 60–63 μ; long. cell., 66–475 μ; crass. zygosp., 50–54 μ; long. zygosp., 73–92 μ.

Habitat:—In a rain-water pool, along with *Anabaena ambigua, Anabaena sphaerica* var. *attentuata* and also sterile filaments of *Spirogyra* and *Oedogonium.*

The form differs from the type in the presence of smaller zygospores and longer conjugation canals.*

Forma.

Lat. cell., 60–64 μ; long. cell., 40–100 μ; crass. zygosp., 56–62 μ; long. zygosp., 70–105 μ, average 89 μ.

Habitat:—In a road-side channel.

The form differs from the type in possessing 2–3 chloroplasts and zygospores with a thin mesospore.

18. *Spirogyra nitida* (Dillwyn) Link. Borge and Pascher, *op. cit.,* 1913, p. 26, Fig. 37; Jao, Studies on the Fresh-water algae of China, I. Zygnemataceae from Szechwan, *Sinensia,* Vol. 6, No. 5, 1935, Pl. VI Figs. 70 and 71.

Forma (Fig. 5, *C*).

Lat. cell., 79–89 μ, average 82μ; long. cell., 40–224 μ; crass. zygosp., 52–62 μ; long. zygosp., 73–100 μ.

Habitat:—In a rain-water pool, Kanwa.

The form differs from the type in the filaments being on the average broader and in the smaller zygospores with more or less rounded ends.

19. *Spirogyra setiformis* (Roth) Kützing. Czurda, *op. cit.,* 1932, p. 192, Fig. 202.

Forma.

Lat. cell., 92–105 μ, average 100 μ; long. cell., 85–135 μ; crass. zygosp., 60–69 μ, average 66 μ; long. zygosp., 95–125 μ.

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* The conjugations canals of the type are described to be very small (only one-fifth of the breadth of the filaments) but the figures given for the form (Czurda, *op. cit.,* 1932, Fig. 200) do not give the correct idea in this respect.

Habitat:—In a rain-water pool along with species of *Gomphonema* and *Navicula.*

The form differs from the type in the possession of narrower zygospores.

Var. *maxima* var. nov. (Fig. 5, *D*).

Vegetative cells as long as broad or upto six times as long as broad; end-walls plane; chloroplasts 5–8. Conjugation scalariform; fructifying cells unswollen. Zygospores ellipsoidal with pointed ends; exospore thick, smooth and hyaline; mesospore thick, smooth and yellow; endospore indistinct.

Lat. cell., 114–132 μ; long. cell., 132–684 μ; crass. zygosp., 82–92 (–102) μ; long. zygosp., 132–171 μ.

Habitat:—In a rain-water pool, Sarnath, along with *Spirogyra Weberi* forma, *S. paradoxa* sp. nov., *S. neglecta* and also sterile filaments of *Oedogonium* and *Zygnema.*

The variety agrees with the type in the plane end-walls, scalariform conjugation, unswollen fructifying cells, ellipsoidal zygospores, with a smooth and hyaline exospore, thick, smooth and yellow mesospore but differs from the same in the presence of much broader cells and the much longer zygospores with a thick exospore. It further differs in the chloroplasts on the average being fewer.

20. *Spirogyra paradoxa* sp. nov. (Fig. 5, *E*).

Vegetative cells short, as long as, or slightly longer than broad; end-walls plane; chloroplasts 3–4. Conjugation scalariform; fructifying cells swollen on the conjugating side and sometimes not swollen on both sides. Zygospores broadly ellipsoidal upto almost spherical; exospore thin, smooth and hyaline; mesospore thin, smooth and brown; endospore indistinct.

Lat. cell., 82–85 μ; long. cell., 80–90 μ; crass. zygosp. spheric., 73–82 μ; long. zygosp. ellipsoid., upto 83 μ.

Habitat:—In a rain-water pool, Sarnath along with *Spirogyra Weberi* forma, *S. neglecta, S. setiformis* var. *maxima* var. nov., and also sterile filaments of *Oedogonium* and *Zygnema.*

The alga belongs to the section 'Conjugata' of the genus on account of the plane end-walls. It can be compared to *Spirogyra margaritata* Wollny and *S. setiformis* (Roth) Kützing in the scalariform conjugation and the unswollen fructifying cells, although the latter are uncommon. It further agrees with the former species in the dimensions of the zygospores, which are sometimes nearly spherical and with the latter species in having also ellipsoidal zygospores, though very much broadened, with a thin smooth and hyaline exospore and a smooth and brown mesospore but differs from both in the possession of narrower cells, lesser number of chloroplasts and the fructifying cells, which are commonly swollen on the conjugating side. It further differs from the former species* in the zygospores being commonly ellipsoidal and from the latter species in the presence of smaller zygospores (that are also sometimes spherical†) with a thin mesospore.

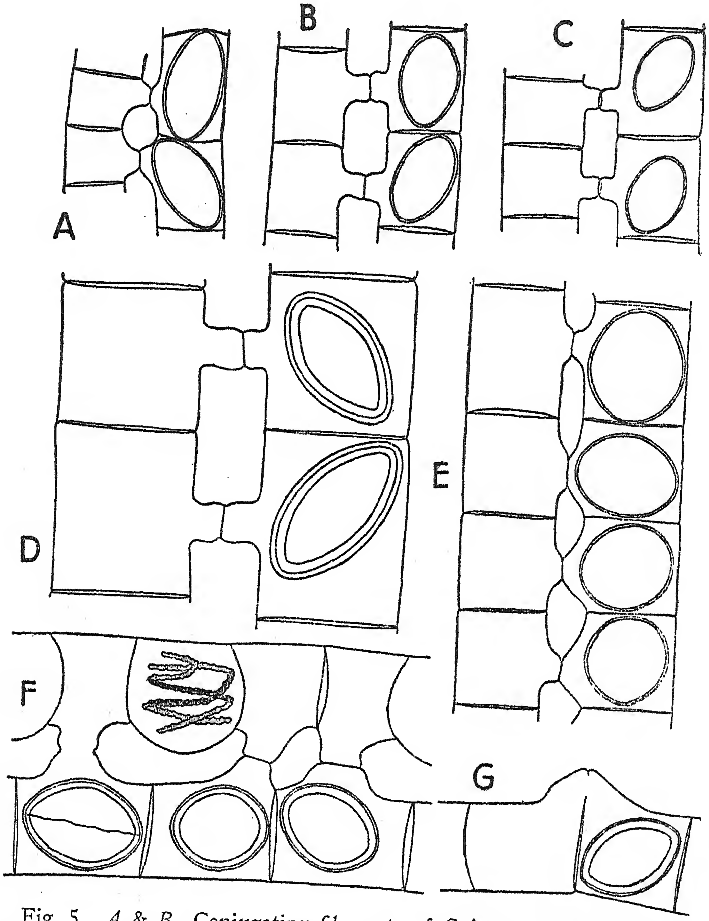

Fig. 5. *A* & *B*—Conjugating filaments of *Spirogyra neglecta* (Hassall) Kützing forma *tennuis* form nov. and *forma* respectively with zygospores; *C*—the same of *Spirogyra nitidia* (Dillwyn) Link *forma; D*—the same of *Spirogyra setiformis* (Roth) Kützing var. *maxima* var. nov.; *E*—the same of *Spirogyra paradoxa* sp. nov.; *F* and *G*—the same of *Spirogyra plena* (N. et G. S. West) Czurda *forma.*

A–E ×130; *F* and *G* ×240.

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* The description given for *Spirogyra margaritata* Wollny (Czurda, *op. cit.*, 1932, p. 192) is incomplete and it is therefore not possible to bring out further points of contrast between this species and the one under discussion.

† The original figure of *Spirogyra setiformis* (Roth) Kützing shows globose zygospores as well but no mention is made about them in the description.

21. *Spirogyra plena* (W. et G. S. West) Czurda. Czurda, *op. cit.,* 1932, p. 193, Fig. 203.

Forma (Fig. 5, *F* and *G*).

Lat. cell., 38–46 μ; long. cell., 50–100 μ; crass. zygosp., (40–) 52 μ; long. zygosp., (50–) 66 (–80) μ.

Habitat:—In a rain-water pool along with *Zygnema cyanosporum.*

The form differs from the type in the zygospores being on the average broader and shorter.

22. *Spirogyra fluviatilis* Hilse. Czurda, *op. cit.,* 1932, p. 199, Fig. 213.

Forma (Fig. 6, *A* & *B*).

Lat. cell., 42–50 μ; long. cell., 45–150 μ; crass. zygosp., 40–53 μ; long. zygosp., 61–75 (–90) μ; crass. cell. fructif., 56–66 μ.

Habitat:—Attached to the rocks of the dam over a canal, Latif Shah, Chakia, Benares State.

The form differs from the type in having broader filaments and shorter zygospores. Further the fructifying cells are not swollen as much as in the type.

23. *Spirogyra verruculosa* Jao. Jao, *op. cit.,* 1936, p. 59, Figs. 32 and 33.

Var. *chakiaense* var. nov. (Fig. 6, *C*).

Vegetative cells as long as broad or shorter or longer; end-walls plane; chloroplasts 4–8. Conjugation scalariform; fructifying cells unswollen. Zygospores ellipsoidal with more or less drawn out ends; exospore thin, smooth and hyaline; mesospore thick, yellowish-brown and verrucose; endospore indistinct.

Lat. cell., 93–104 μ; long. cell., 80–116 μ; crass. zygosp., 50–66 μ; long. zygosp., 73–122 μ.

Habitat:—In a pond, Chakia, Benares State, along with sterile species of *Bulbochaete* and *Spirogyra.*

The variety agrees with the type on account of the scalariform conjugation, unswollen fructifying cells and ellipsoidal zygospores with a thin, smooth and hyaline exospore and a brown and verrucose mesospore, but differs in having narrower cells, and much smaller zygospores with more or less drawn out ends. It further differs in having sometimes more chloroplasts.

Forma.

Lat. cell., 84–92 μ, average 89 μ; long. cell., 80–165 μ; crass. zygosp., 60–82 μ; long. zygosp., 100–138 μ.

Habitat:—In a rain-water pool along with a sterile species of *Spirogyra.*

This form differs from the type just in the same way as the above variety but it possesses slightly narrower cells and on the average bigger zygospores than the latter form.

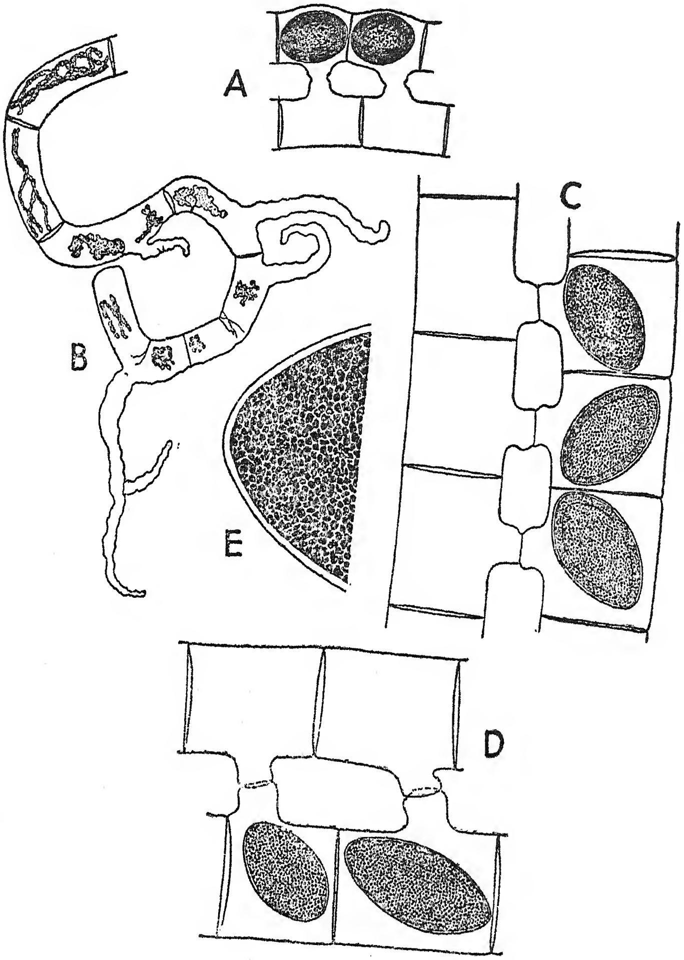

Fig. 6. *A*—Conjugating filaments with zygospores and *B*—basal portion of a filament with the rhizoids of *Spirogyra fluviatilis* Hilse *forma; C*—conjugating filaments with zygospores of *Spirogyra verruculosa* Jao var. *chakiaense* var. nov.; *D*—conjugating filaments with zygospores and *E*—a portion of a highly magnified zygospore showing the surface sculpture of *Spirogyra anamola* sp. nov.

A, C & D ×130; *B* ×70; *E* ×585.

24. *Spirogyra anamola* sp. nov. (Fig. 6, *D* & *E*).

Vegetative cells shorter or longer than broad; end-walls plane; chloroplasts 5–10. Conjugation scalariform; fructifying cells unswollen. Zygospores ellipsoidal with pointed ends; exospore thin, smooth and hyaline; mesospore thick, brown and closely reticulate sculptured; endospore indistinct.

Lat. cell., 108–125 μ, average 115 μ; long. cell., 72–165 μ; crass. zygosp., 73–90 μ; long. zygosp., 108–138 (–165) μ, average 115–135 μ.

Habitat:—In a road-side puddle, Sarnath.

The alga belongs to the section 'Conjugata' of the genus and may be compared with *Spirogyra Reinhardii* Chmielewski and *S. paraguayensis* Borge on account of the scalariform conjugation and ellipsoidal zygospores with a sculptured mesospore. It further agrees with the former species in the thickness of the filaments, and with the latter species in the unswollen fructifying cells. But it differs from both in having more chloroplasts, and in the sculpture on the mesospore being very closely reticulate. It further differs from the former species in the unswollen fructifying cells and narrower zygospores that are frequently shorter, and with the latter species, rather remarkably, in having much broader filaments and much bigger zygospores.

25. *Spirogyra brunnea* Czurda. Czurda, *op. cit.*, 1932, p. 197, Fig. 210.

Forma *varians* form. nov. (Fig. 7, *A–C*).

Lat. cell., 46–56 μ; long. cell., 110–258 μ; crass. zygosp., 46–63 μ; long. zygosp., 60–79 (–86) μ; crass. cell. fructif., 66–70 (–90) μ.

Habitat:—In a shallow pond along with a sterile species of *Zygnema*.

The form differs from the type in the presence of narrower cells, fructifying cells being also unswollen on one or both sides and frequently shorter zygospores with a more regular sculpture on the mesospore.

(B) MOUGEOTIACEAE

Genus *Mougeotia* Agardh

26. *Mougeotia calcarea* (Cleve) Wittrock. Czurda, *op. cit.*, 1932, p. 63, Fig. 34.

Lat. cell., 12–15 μ; long. cell., 80–118 μ; crass. zygosp., 30–36 μ; long. zygosp., 40–43 μ.

Habitat:—In a puddle just by the side of the river Ganges along with a sterile species of *Zygnema*.

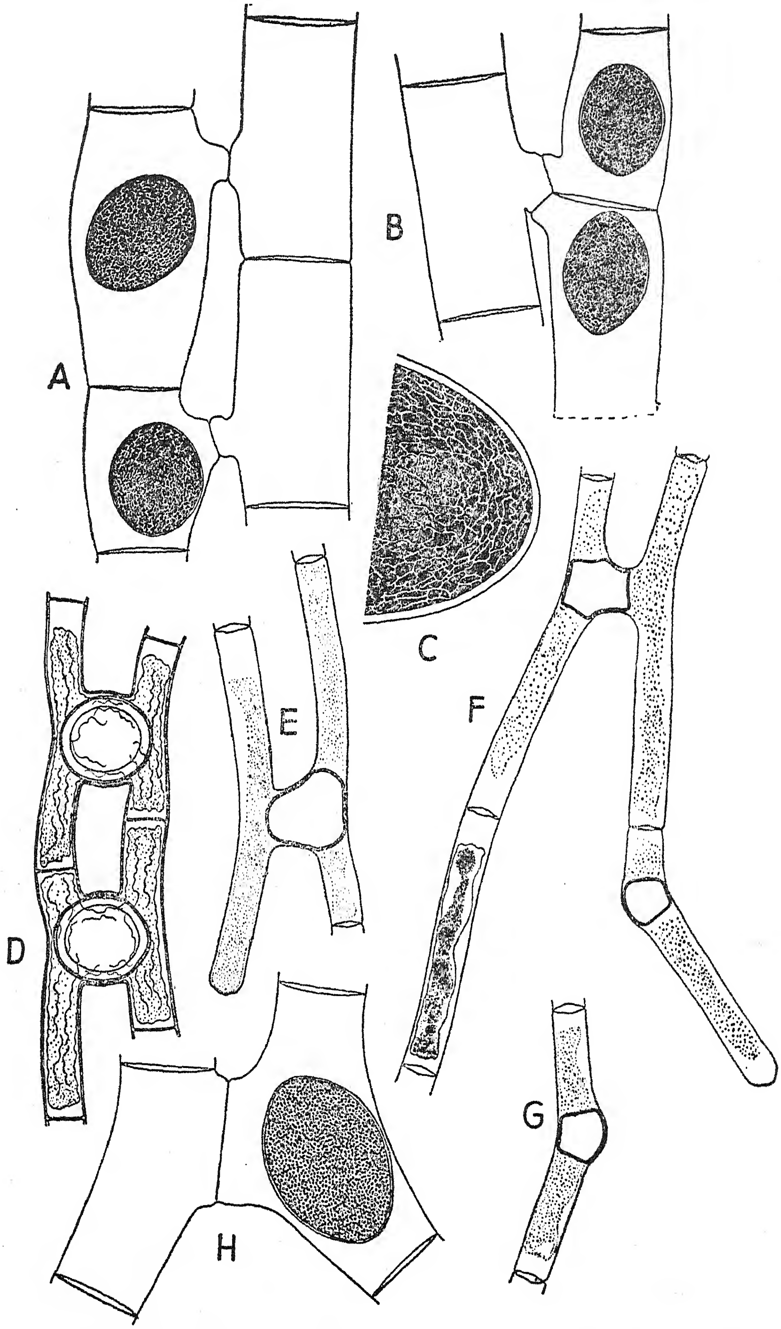

Fig. 7. *A* & *B*—Conjugating filaments with zygospores and *C*—a portion of a highly magnified zygospore showing the surface sculpture of *Spirogyra brunnea* Czurda forma *varians* form. nov.; *D*—conjugating filaments of *Mougeotia sphaerocarpa* Wolle. *forma* with zygospores; *E* & *G*—the same of *Mougeotia tenuis* (Cleve) Wittrock; and *H*—conjugating filaments of *Sirogonium ventersicum* Transeau var. *megaspora* var. nov. with a zygospore.

A & *B* ×240; *C* ×585; *D-G* ×285; and *H* ×130.

27. *Mougeotia sphaerocarpa* Wolle. Czurda, op. cit., 1932, p. 68, Figs. 43 and 44.

Forma (Fig. 7, *D*).

Lat. cell., 17–20 μ; long. cell., 73–230 μ; crass. zygosp. (36–) 40–46 μ; long. zygosp., 38–46 μ.

Habitat:—In a road-side channel, Benares Hindu University grounds.

The form differs from the type in having narrower cells. The azygospore formation present in the type has however not been observed.

28. *Mougeotia tenuis* (Cleve) Wittrock. Czurda, *op. cit.*, 1932, p. 81, Fig. 66. (Fig. 7, *E–G*).

Lat. cell., 16–18 μ; long. cell., 80–105 μ; crass. zygosp., 30–35 μ; long. zygosp., 33–43 μ.

Habitat:—In the puddles on the sides of the river Ganges, along with *Zygnema gangeticum* sp. nov., *Spirogyra Weberi forma, S. decimina, S. flavescens* and also sterile filaments of *Spirogyra* and *Zygnema.*

The zygospores of the Benares form are however on the average of bigger dimensions.

Genus *Sirogonium* Kütz.

29. *Sirogonium sticticum* Kuetzing. [=*Spirogyra stictica* (Engl. Bot.) Wille]. Czurda, *op. cit.*, 1932, p. 144, Fig. 142; Jao, *op. cit.*, 1935, Pl. XII, Fig. 123; Fritsch, Structure and Reproduction of Algae, Vol. I, p. 332, Fig. 103, *B* and *F*.

Lat. cell., 42–46 μ; long. cell., 100–210 μ; crass. zygosp., 58–66 μ; long. zygosp., 95–100 μ; crass. cell. fructif., upto 70 μ.

Habitat:—In a pond.

30. *Sirogonium ventersicum* Transeau. Transeau, Tiffany, Taft and Li, *op. cit.,* 1934, Pl. XXII, Fig. 65.

Forma.

Lat. cell., 68–79 μ; long. cell., 198–250 μ; crass. zygosp., 88–103 (–118), average 100 μ; long. zygosp., 130–165 (–180) μ; crass. cell. fructif., 132–148 μ.

Habitat:—In a rain-water pool.

The form agrees with the type in all respects except that the chloroplasts are seven to eleven and the zygospores are broader and occasionally also longer.

Var. *megaspora* var. nov. (Fig. 7, *H*).

Vegetative cells upto four times as long as broad; end-walls plane; chloroplasts 7–12, straight or making one turn; fructifying cells inflated. Zygospores ellipsoidal with rounded ends or rarely ovoid; exospore thin, smooth and hyaline; mesospore thin, brown, densely and irregularly verrucose.

Lat. cell., 73–82 μ; long. cell., 148–365 μ; crass. zygosp., 92–121 μ; long. zygosp., 158–250 μ; crass. cell. fructif., 130–165 μ.

Habitat:—In a rain-water pool along with *Anabaena ambigua* Rao and a species of *Gomphonema.*

The variety agrees with the type on account of the ellipsoid or rarely somewhat ovoid zygospores provided with a brown mesospore, that is densely and irregularly verrucose, but differs from the same in having seven to twelve chloroplasts, broader cells and bigger zygospores.

In conclusion, I have pleasure in expressing my great indebtedness to Professor Y. Bhâradwâja, for his kind guidance and criticism. I am also thankful to Professor M. O. P. Iyengar for many helpful suggestions and advice.

SPERMATOGENESIS IN *EICHHORNIA CRASSIPES* SOLMS.

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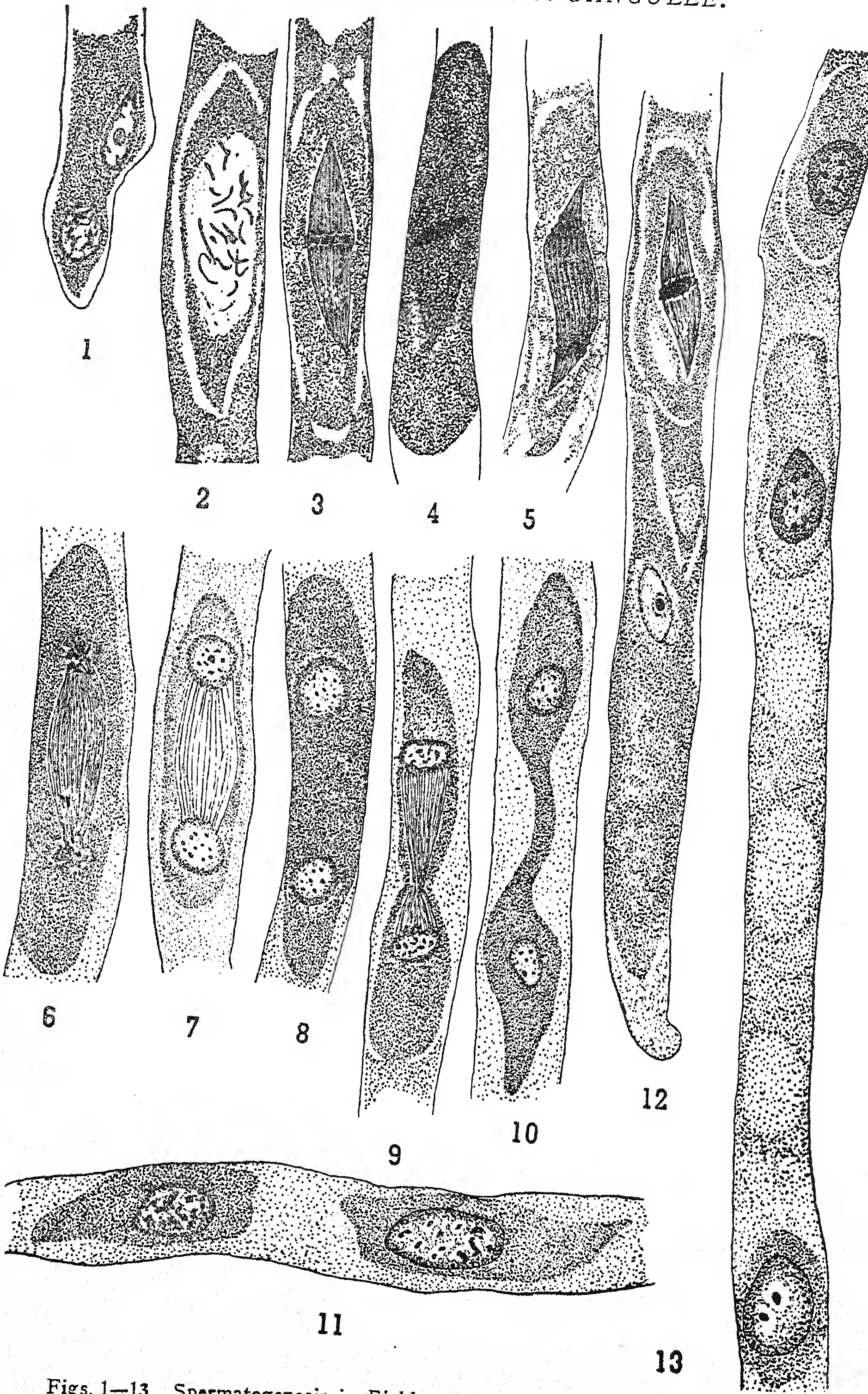
As compared with the vast amount of literature on meiosis, mitosis and other aspects of cytology, the records on the spermatogenesis and fertilisation of angiosperms are rather scanty. Even of this scanty work most of the earlier investigations came as a side issue along with detailed work on microsporogenesis and embryology. It is only in recent years that detailed work on the spermatogenesis of certain families of angiosperms has been taken up.

Most of the work on spermatogenesis has been done on Liliaceous plants characterised by large chromosomes. In these plants the mode of spermatogenesis as revealed by the investigations of Strassburger (1900, 1901), Nawaschin (1910), Welsford (1914), O'Mara (1933), Hoare (1934) and others appears to be somewhat peculiar. The generative cell in a state of early or late prophase enters the pollen tube and becomes elongated and narrow. The chromatin thread, at first irregular, finally breaks up into the large chromosomes and the nuclear membrane disappears. No achromatic figure is formed nor any equatorial plate is noted. The chromosomes lie irregularly distributed and after division the daughter halves 'somehow reach the opposite poles'. Cytokinesis takes place by constriction and two male cells are formed.

Working on non-Liliaceous plants other workers, especially Ishikawa (1918), Wylie (1923), Finn (1928–1930), Rudenko (1929–1930) and Madge (1930), have noted complete male cells arising out of a clear mitotic division. Achromatic figures with an equatorial arrangement of the chromosomes at metaphase were seen in these cases. Some of the investigators have observed cytokinesis to take place by means of a cell-plate, while others have observed constriction of the cytoplasm.

The earliest cytological work on the family Pontederiaceae is that of Smith (1898). He worked out the microsporogenesis and megasporogenesis of *Eichhornia crassipes.* Schurhoff (1922) has worked on the anomalous division of the vegetative cell in the pollen grains of *Eichhornia crassipes.*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Figs. 1—13. Spermatogenesis in *Eichhornia crassipes* Solms. Fig. 1. Genera-

Material and Methods

The material for study was obtained from plants grown in water-tubs and kept in the college compound. Inflorescences obtained from outside sources and kept with their cut ends immersed in beakers containing water were found to be useless for the study, as the pollen grains did not germinate on the stigmas of flowers of such inflorescences after hand pollination. Pollen grains obtained from dehisced anthers were fixed and stained on the slide according to Barrett's (1932) method.

For the study of spermatogenesis flowers were hand pollinated and the styles of those flowers were fixed at intervals of 1, 1½, 2, 3, 4, 5 and 6 hours. Mature anthers were fixed separately.

Of the fixing fluids employed Allen's modified Bouin's fluid and La Cour's fluid 2BE gave the best results. The material was dehydrated, cleared and embedded in the usual way. Sections were cut 8 to 10 microns thick and stained with Heidenhain's haematoxylin.

Another method tried was to tease out under the microscope the growing pollen tubes from the stylar canals a few hours after pollination. The pollen tubes thus obtained occurred in bunches and were so greatly convoluted that it was not possible to disentangle them and trace the entire length of any one of them. As such this method did not prove successful.

Observations

The Pollen Grains.—The pollen grains at the time they are liberated from the microsporangium are oval in shape. After pollination they swell, become round in form and then germinate on the stigma. The pistil is formed of three united carpels. The stigma is capitate and slightly trifid. Germination of the pollen grains takes place within half an hour of pollination. The pollen tubes make their way through the unicellular stigmatic hairs and soon reach the stylar canals through which they continue their downward course. Inside the stylar canals they could be seen in large numbers and they follow a slightly sinuous course. In transverse sections of the style the pollen tubes appear as small circular discs located inside the stylar canals. In longitudinal sections through the stylar canals the pollen tubes are seen in bunches. The growth of the pollen tube is very rapid, tubes one millimetre in length being observed 30 minutes after pollination. Pollen tubes were observed to reach the ovules, a distance of about an inch, at the end of eight hours.

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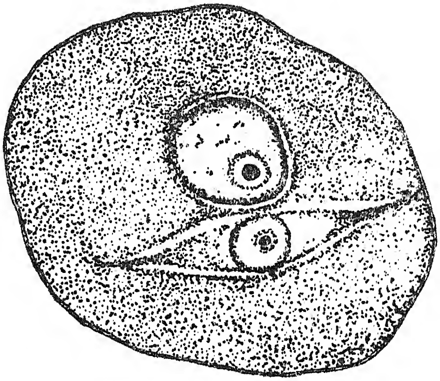
tive nucleus in early prophase, and preceded by the vegetative nucleus. × 1,300. Fig. 2. Late prophase of the generative nucleus. Chromosomes organised. × 1,500. Fig. 3. Metaphase. × 1,500. Fig. 4. Metaphase. Note the oblique position of chromosome plate. × 1,500. Fig. 5. Anaphase. Fig. 6 & 7. Telophase. × 1,500 Fig. 8. Daughter nuclei before cytokinesis. × 1,500. Fig. 9. Cytokinesis by constriction. × 1,500. Fig. 10. Cytokinesis. In this it appears that the two nuclei are drawn away from one another. ×1,500. Fig. 11. The sperm cells. Nucleoli are not yet organised. × 1,500. Fig. 12. Metaphase stage of generative nucleus with vegetative nucleus leading. × 1,500. Fig. 13. The sperm cells with undisorganised vegetative nucleus leading. × 15,000.

The mature pollen grain is binucleate, containing a vegetative and a generative cell (Fig. 14). The vegetative nucleus is large with a nucleolus and numerous chromatin granules distributed throughout the nucleoplasm. The generative nucleus is small and less chromatic. The cytoplasm is spindle-shaped with pointed ends. In preparations which seem to be badly fixed the prolongations of the cytoplasmic spindles appear as long flagella.



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Text fig. 14. Spermatogenesis in *Eichhornia crassipes* solms. ×1,300

Spermatogenesis.—The generative nucleus enters the pollen tube in a state of early prophase. It is somewhat elongated at this stage and rapidly divides in the ordinary mitotic manner to form two distinct male cells. The division is extremely rapid as seen by the scarcity of actual dividing stages and predominance of pollen tubes with fully formed male cells. Four hours after pollination all the generative nuclei seem to complete their division inside the pollen tubes. The stages of mitotic division are found near the stigma, while the male cells are found at all distances inside the stylar canals.

It has already been mentioned that the generative nucleus, when it enters the pollen tube, is in the prophase stage. Figure 1 shows such a stage, where the vegetative nucleus occurs at the tip of the pollen tube and precedes the generative nucleus. In the next stage, (Fig. 2) the spireme has segmented into the component chromosomes. The nuclear membrane has disappeared, though the spindle-fibres have not as yet appeared. The chromosomes are somewhat V-shaped, and are distributed in the cytoplasm without any regular arrangement. These stages were found with great difficulty and seem to occur very early in the life history of the generative cell.

The chromosomes soon arrange themselves in a clearly defined equatorial plate, the spindle is quite normal and the spindle-fibres are well defined. Figure 3 shows an equatorial plate at right angle to the axis of the spindle. Figure 4, however, shows an equatorial plate which is slightly inclined instead of being at right angles to the axis.

During anaphase the chromosomes move towards the two poles in the usual course. Figure 5 represents such a stage. The movement of the chromosomes appears to be quite regular.

In the telophase the daughter chromosomes at the two poles begin to constitute themselves into two daughter nuclei. Figure 6 represents a stage where the chromosomes have just reached the poles. The chromosomes gradually condense and the daughter nuclei now develop a nuclear membrane. The spindle-fibres are noted even at this stage (Fig. 7). In the daughter nuclei the chromosomes do not lose their identity, but retain their separate existence as chromatic dots.

The spindle-fibres of the cytoplasm gradually disappear, and no evidence of cell-plate formation is seen. At first the daughter nuclei remain free at the two ends of the homogenous cytoplasm of the generative-mother cell (Fig. 8). At a later stage the middle portion of the cytoplasm seems to constrict. This constriction gradually increases and finally separates the two daughter nuclei (Figs. 9 and 10). The two cells thus formed are equal in size (Fig. 11). The nucleus contains the chromosomes in the form of chromatin particles throughout their development and these lose their identity only at a very late stage.

The vegetative nucleus could not be followed during the division of the generative nucleus, as it was difficult to find sufficiently long lengths of pollen tubes in any preparation showing both of them. It was, however, not found to disorganise during stages of spermatogenesis. It always preceded the generative nucleus (Figs. 12 and 13).

Discussion

Binucleate pollen grains have been observed in *Eichhornia crassipes* by Smith (1898), Schurhoff (1922) and others. Both the authors noted the vegetative nucleus to be in a state of division. Schurhoff ascribes this condition to a "pathologisches verhalten durch die klimatischen verhaltnisse". Smith's description of the binucleate pollen grain is open to criticism. He states that the generative nucleus does not contain any nucleolus, but is uniformly filled up with chromatic material and that the generative cell possesses two long flagella-like processes. In the present investigation distinct nucleolus has been observed to be present inside the generative nucleus. The flagella-like processes mentioned by Smith may be due to the thinning out of the ends of the generative cell due to bad fixation.

The generative nucleus enters the pollen tube while in a state of prophase. Similar condition of the generative nuclei at a similar stage has been noted in *Scilla non-scripta* by Hoare (1934) and by Finn in several plants. In metaphase an equatorial plate, and spindle-fibres have been noted and this appears to be a characteristic feature of non-Liliaceous plants. An inclined equatorial plate as observed by Rudenko (1930) in *Lathrea* has also been observed in this plant. The appearance of this inclined spindle is probably due to the restricted space within the pollen tube, in which a number of chromosomes are to be accommodated. It is interesting to note in this connection Wulff's (1935) studies on *Narthecium ossifragum,* a Liliaceous plant. He found the presence of an equatorial plate and spindle-fibres in pollen tubes grown in cultures, whereas these were absent in pollen tubes seen in longitudinal sections of previously pollinated styles. The pollen tubes grown in cultures were 5–7 times broader. It has been suggested that the non-appearance of the equatorial plate and spindle-fibres may be due to a spatial factor, "for tubes in the style are too narrow to permit the formation of a normal equatorial plate". During cytokinesis normal deposition of partition walls has been observed in a number of plants, but no cell-plate has been observed by Madge (1930) working on *Viola* and by all the investigators working on Liliaceous plants. In the present material also no cell-plate has been observed. The generative nuclei are enclosed by a cytoplasmic sheath and the sperms do not appear as naked male nuclei. Earlier investigators failed to observe this sheath in the Liliaceous plants they studied. Later work has shown that though sperm cells are formed as the result of the division of the generative nuclei, only naked sperms are found at the time of fertilisation (Trankowski 1930) the cytoplasmic sheath of the nucleus being shed at a certain stage prior to fertilisation.

Summary

1. The mature pollen grains are bi-nucleate and spermatogenesis takes place in the pollen tube.

2. The generative nucleus enters the pollen tube in a state of prophase. A well differentiated equatorial plate and spindle-fibres are noted at metaphase and the other stages of the mitotic division are also normal. Cytokinesis takes place by constriction and two independent male cells are formed.

3. The vegetative nucleus precedes at first the generative nucleus, and later the male cells. It does not show any sign of degeneration while inside the stylar canal.

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MEGASPOROGENESIS IN *ALOE VERA* LINN.

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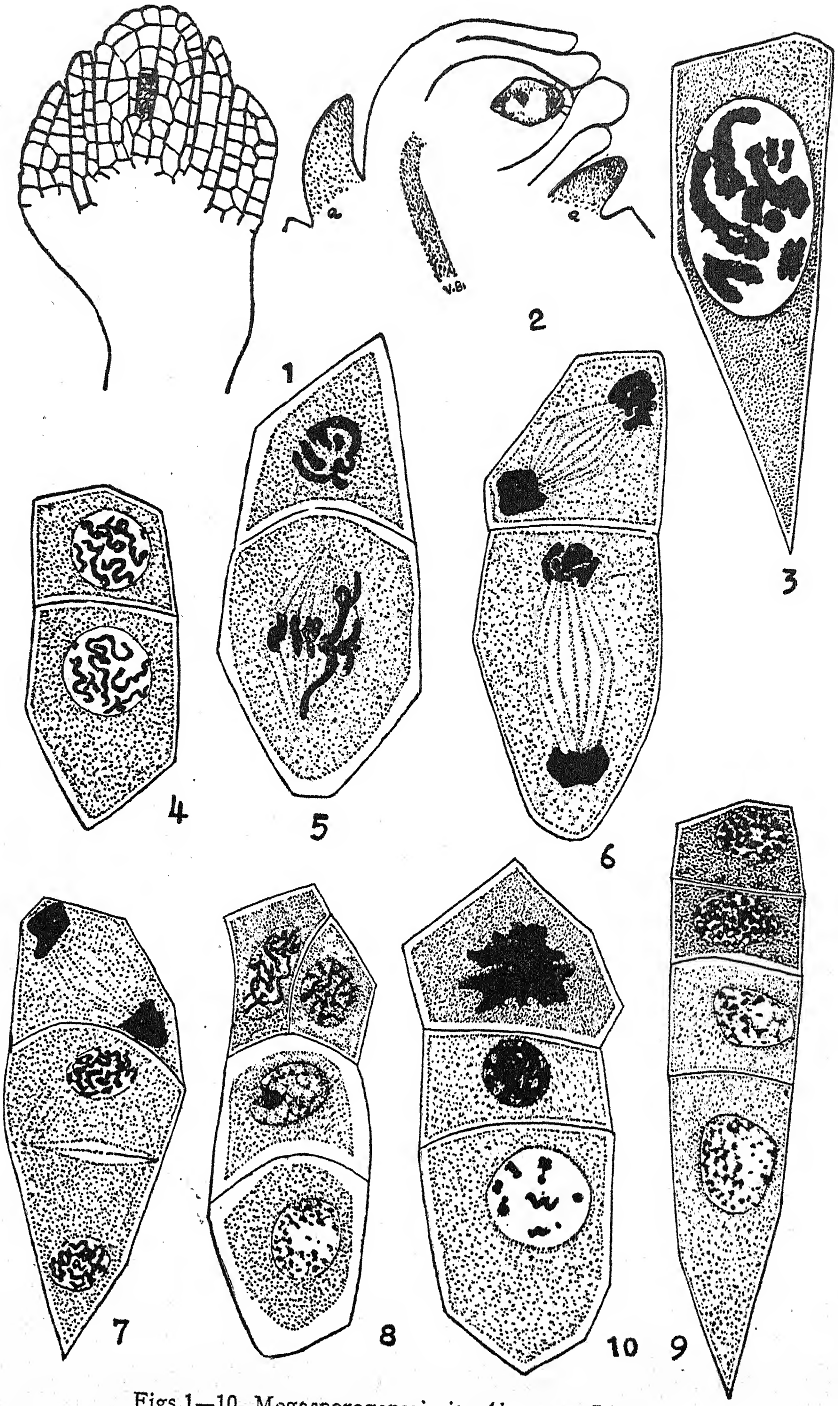
The development of the embryo-sac in the genus *Aloe* has been studied by Gioelli (1930). Five species, namely *arborescens* Mill., *Todari* var. *præcox* Borzi, *cæsia* Salm., *Varvari* Borzi and *Ciliaris* Haw., were investigated and it has been reported that in every case the development of the embryo-sac follows according to the *Lilium*-type, or what we would now call in the light of recent embryological investigations of Bambicioni (1928 *a* and *b*). Bambicioni and Giombini (1930), Cooper (1935) and Romanov (1936) on *Fritillaria, Tulipa, Lilium* and *Gagea* as the *Adoxa*-type. The megaspore-mother cell directly gives rise to the embryo-sac as a result of three free nuclear divisions and no megaspores are formed. In the sub-tribe Aloineae of the family Liliaceæ, the development of the embryo-sac has been worked out in two other genera *Haworthia* and *Gasteria* by Mellink (1880) and Stiffler (1925) respectively and in both it has been found to follow the normal type. This difference in the development of the embryo-sac of closely related genera appears unusual. A reinvestigation of the embryology of the genus *Aloe* has therefore been undertaken.

The species studied is *Aloe vera* Linn., the most commonly cultivated aloe in the plains of Northern India. Material of this was obtained from the local botanical garden. It was fixed in Nawashin's fluid, and embedded and microtomed according to the customary methods. Heidenhain's iron-alum hæmatoxylin was used for staining the sections.

Observations

Ovule. The ovules remain straight for a long time. Fig. 1 shows a longitudinal section of an ovule containing a dyad and it is still in the orthotropous condition. The ovules retain this form even up to the formation of the megaspores. Only after the megaspores have been formed, the ovules begin to show a marked curvature, but even when containing mature embryo-sacs they are only semi-anatropous (Fig. 2).

There are two integuments in the beginning (Fig. 1), out of which the inner alone takes part in the formation of the micropyle (Fig. 2). After the formation of the megaspores, as the ovules begin to curve, a third integument or aril arises below the outer integument. Its further growth leads to the formation of a cup-like investment around the chalazal region of the ovules (Fig. 2).



Figs.1—10. Megasporogenesis in *Aloe vera* Linn.

Fig. 1—An ovule at the dyad stage. × 180. Fig. 2.—An ovule at the mature embroyo-sac stage. a aril; v. b., vascular bundle of the ovule. ×80. Fig. 3—A megaspore-mother cell at the diakinesis stage. The nucleus shows seven bivalents and a lightly staining nucleolus. × 1100. Fig. 4.—A dyad with the

The inner integument is two cells thick except in the region of the micropyle, where it generally consists of three or four layers of cells. The outer integument is mostly three cells thick. The aril consists through its greater length of 3—5 layers of cells. The nucellus is comparatively small in size. At the megaspore-mother cell stage, there are two layers of parietal cells below the epidermis (Fig. 1). During the development of the embryo-sac, both of these layers are crushed and absorbed, so that the mature embryo-sac, comes to lie just below the epidermis (Fig. 2). The whole form and structure of the ovule is in fact very similar to that of *Asphodeline lutea* sketched by Schnarf (1931).

Megasporogenesis. The primary archesporium is limited to a single cell. A primary wall cell is cut off, which by further divisions gives rise to the two layers of parietal tissue already mentioned.

The first divison of the megaspore-mother cell is heterotypic. The chromosomes are seen to pair regularly during the prophase of this division (Fig. 3). The telophasic chromosomes organise into definite nuclei. A cell plate appears at the end of this division. A regular dyad is thus formed (Fig. 4). The next division is homotypic. Nuclei of both the dyad cells generally begin to divide simultaneously (Figs. 5 and 6), but the division in the micropylar cell slows down in the last stages and the chalazal cell completes the division earlier (Fig. 7). The spindle in the chalazal dyad cell is orientated longitudinally. In the micropylar cell, it is generally placed obliquely, but sometimes in this cell also it may be placed nearly longitudinally. A cell plate is formed regularly in the chalazal cell at the end of this division. In the micropylar cell, it may be formed or may not be. When it is formed, as a result of the previous orientation of the spindle, it is generally orientated more or less longitudinally, but rarely, when the spindle has this direction, the cell plate may be placed transversely. The form of the tetrad of megaspores is thus variable. It may be T-shaped (Fig. 8) or linear, (Fig. 9). In other cases, the cell plate appears at the end of the homotypic division only in the chalazal dyad cell, in the micropylar dyad cell the telophasic spindle fibres disappear without the appearance of any cell plate. A linear row of three megaspores only is consequently formed, of which the micropylar contains two sets of chromosomes or nuclei (Fig. 10). The occurrence of T-shaped tetrads or a row of three megaspores out of which the micropylar is 2-nucleate has also been observed by Stiffler (1925) in *Gasteria.*

In *Aloe vera* thus the megaspore-mother cell regularly gives rise to four or three megaspores. Out of these, the chalazal develops into the embryo-sac in the normal manner. The development of the embryo-sac, therefore, does not correspond to the *Lilium* or the *Adoxa*-type as concluded by Gioelli (1930).

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nuclei in prophase. No nucleolus is seen in the nuclei. × 1100. Fig. 5.—Second division of the megaspore mother cell; metaphase. × 1100. Fig. 6.—Same as Fig. 5; telophase. The spindle in the micropylar dyad cell is obliquely orientated. × 1100. Fig. 7.—A late stage of the telophase of the second division. Cell plate has appeared in the chalazal dyad cell but not in the micropylar. × 1100. Fig. 8.—A T-shaped tetrad of megaspores. × 1100. Fig. 9.—A linear tetrad of megaspores. × 1100. Fig. 10.—A row of three megaspores, the chalazal the largest, the micropylar with two degenerating groups of chromosomes. × 1100.

Chromosomes. The number and form of the chromosomes in *Aloe vera* is shown by Fig. 3. There are seven bivalents. The diploid number of chromosomes is therefore fourteen. Eight out of these are long and six small. This confirms the report of Sutaria (1932) made from a study of somatic nuclei.

Summary

The megaspore mother cell in *Aloe vera* does not give rise to the embryo-sac directly. It either gives rise to a T-shaped or linear tetrad of megaspores or to a linear row of three megaspores of which the micropylar contains two sets of chromosomes or nuclei due to the failure of cell plate formation in the micropylar dyad cell at the end of the homotypic division. The chalazal megaspore alone gives rise to the embryo-sac. The development of the embryo-sac corresponds to the *Normal*-type.

These observations differ from those of Gioelli.

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NOTE ON PHENOLOGICAL OBSERVATIONS TO BE MADE IN INDIA

BY

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Received for publication on the 5th September 1937

Attention has been drawn by the International Commission on Agricultural Meteorology to the desirability of collecting phenological records, and the help of botanists has been asked for drawing up a list of plants and phytophases which are likely to prove most suitable for the purpose. No systematic work appears to have been done in India though this field has been intensively developed in Europe and Great Britain, very largely by organising the voluntary services of amateur observers distributed throughout the country. A great deal of attention has also been given to it in North America where Dr. Hopkins has done pioneer work in deducting bioclimatic laws of general applications over a large tract of country and shewing the value of such work to agricultural practice.

The climatic conditions of two sites in a tract of country are effectively reflected in the average dates on which plants of the same race and species enter on their various phytophases, provided other growing conditions are comparable. Species of wide distribution are the most suitable for observation in that they permit comparison between widely separated sites, and hardy species which can adapt themselves to very varied conditions are also desirable. The relative advantages of trees over herbs and low shrubs are universally recognised and need not here be discussed, but the flowering and planting of some grasses such as *Saccharum spontaneum* and *S. Munja* may be worth considering. The plants selected should be of common occurrence and unlikely to be confused with other allied species as the help of amateur workers is required. Many cultivated plants present the advantage of being available over most of the country but have been segregated under cultivation into a number of strains, etc., often with markedly different phenological behaviour which is liable to render them quite unsuitable for use as measures of climate since such strains are usually very difficult to distinguish. On the other hand some, such as the Lombardy poplar, may be genetically purer than most wild plants. Not a few of the common trees of India which suggest themselves appear less suitable on closer study, as consisting of a complex of genotypes which may, and sometimes do, vary in their phenolgical characteristics. Thus *Butea frondosa* and *Schleichera trijuga* have been found as a result of the attention which has been concentrated on them as lac hosts to include several recognisable forms which come true to seed. Many other species of wide distribution among which the Teak and *Acacia Catechu* may be mentioned, consist of a number of geographical races whose characteristics including phenological behaviour are inherent in the seed, and persist when the plants are raised in a new locality; but provided observations are restricted to naturally growing plants this is probably no disadvantage in the present connection—perhaps the contrary.

Phytophases are generally much more clearly defined in temperate and cold climates than in the usual Indian subtropical and tropical monsoon climate and become still less sharp in warm or tropical moist climates of those parts of the country which do not experience a marked cold or dry season. This easily observed fact is borne out by experience gained at the Forest Research Institute, Dehra Dun, U.P., since 1928 when regular observations were begun on a number of trees.

Leaf-fall has proved a most unsatisfactory phase for observation in India and may be rejected except for the temperate Himalayas. Leafing is often well defined for deciduous species (*e. g. Dalbergia Sissoo*) and for some evergreen also (mango). Flowering is found to be the best defined phase and fortunately we have species which flower at different times practically all through the year.

Ripening of fruit to be satisfactory for our purposes usually requires to be associated with a marked colour change or formation of an abscission layer as with *Desterocarps*, etc., and this tends to limit the choice available.

The suggested international photophases are obviously only applicable to Northern Europe and only one of the species mentioned even extends into India. We have therefore to make our own selection in which we should if possible include one or two European or other exotics which might later render some degree of correlation possible. Despite the wide range of latitude in India, the summer deciduous forests extend without great difference in appearance and specific composition from North to South, and there should be no great difficulty in finding acceptable species and phases covering this large proportion of the country. Some species extend from this type into the drier country of the N.W. and others into the moist sub-evergreen tracts. The wet tropical parts of the country could probably not easily be fitted in, though not a few of the same trees are found in them in re-growth after clearing, planted about towns and villages, or wherever the original forest has been much opened up or destroyed. Though many of the indigenous species of the wet tropical forest appear to exhibit a much less well defined seasonal history, it is not improbable that closer study would reveal some phases suitable for observation (flowering of *Hopea*).

Experience shows that it is very difficult to determine the general date for a given stage of the selected species over a tract of country, and that it is better to concentrate attention on given trees or groups of trees. At the Forest Research Institute, I have preferred a limited number, 5-10, usually scattered over a few miles of country.

These trees are chosen as of normal growth, not exposed to any unusual conditions such as proximity to water channels, exceptionally exposed or sheltered position, etc. In the hills, altitude and exposure are of course very influential and must be carefully recorded; it is desirable to replicate observations for different elevations and aspects represented at any stations, as far as this is practicable. Observations are made every few days during the important periods of change for which records are required, and an estimate given of the exact date of the change if it falls between two inspections. Any tree which is observed during the year to be behaving markedly differently from the others is replaced the following year by a more normal one, thus for *Shorea robusta*, one tree originally selected was found to flower about 3 weeks later than the others.

In South India trees worth consideration in this connection are *Hopea parviflora*, *Anacardium occidentale*, *Lagerstroemia lanceolata*, and *Terminalia paniculata.*

Cultivated exotic plants avilable in most stations such as *Jacaranda* and *Poinciana regia* have been suggested as convenient, but the writer feels that it is preferable to work as far as possible with our indigenous species.

Suitable trees and phases to cover the year.

Season in North India	Species	Phytophase to be observed	Remark
January February	*Bombax malabaricum.*	Commencement of flowering.	Period rather variable and drawn out calling for careful selection of trees.
February	*Dalbergia Sissoo* *Cedrela Toona.*	Commencement of leafing.	*Cedrela Toona* is widespread but may be confused with allied species.
March-April	*Mangifera indica* *Shorea robusta* *Butea frondosa,* *Azadirachta indica.*	Flowering.	Wild mango only.
April-May	*Cassia fistula,* *Tamarindus indicus*	Flowering.	———
May-June	*Terminalia tomentosa.*	Leafing.	Complex species perhaps unsuitable.
June-July	*Bassia latifolia.* *Shorea robusta.*	Fall of fruits.	———
Aug.-Sept.	*Tectona grandis.*	Flowering.	———
October	*Bauhinia purpurea.*	Flowering.	Species somewhat local.
Oct.-Nov.	*Michelia Champaca.*	Ripening of fruits.	Recognised by colour.
Nov.-Dec.	*Zizyphus jujuba.* *Melia Azedarach.*	Ripening of fruits.	Not very well defined.

In the lower hills of Northern India, *Pinus longifolia* is an obvious species to use, pollen shedding being the best defined phase, and commencement of bud elongation is also suitable. Other possibilities here are the flowering of *Rosa moschata* and *Cedrela Toona* and fruiting of *Rubus ellipticus*, but often only the trees of cultivation are available in the *chir* pine zone. Higher up, in the temperate forests, the choice is wider, and as in Europe, leafing and leaf-fall are marked enough to be serviceable.

Suggestions are :—

Season	Species	Phytophase	Remark
April	*Quercus incana.*	New leaves	
April-May	*Rhododendron arboreum.*	Commencement of flowering.	
May-June	*Rosa macrophylla,* *Rosa moschata,* *Aesculus indicus.*	Flowering.	
June-July	*Bulbous herbs.*	Flowering.	
Sept.-Oct.	*Aesculus indicus.* *Cedrus Deodara,* *Abies Pindrow.*	Fruit fall; pollen shedding and seed fall.	
Oct.	*Acer* spp. *Populus* spp.	Leaf fall.	
Oct.-Nov.	*Cedrus Deodara.*	Seed fall.	

Standardised forms both for recording and summarising are always convenient and become a necessity when compiling and averaging the records of many stations. Such forms are in use in Western countries and can conveniently be amended and adapted to use in this country as indicated by the example with general instructions already circulated to the Committee.

A NOTE ON THE UREDO ON *JASMINUM MALABARICUM* WIGHT

BY

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Received for publication on the 5th September 1937

Communicated by S. L. Ajrekar

The author of this note, in collaboration with Prof. S. L. Ajrekar, has published *an account of his observations on two rust fungi on *Jasminum malabaricum* and *Jasminum grandiflorum* and has given reasons to believe that the Uredo stage on *Jasminum malabaricum* is a distinct rust and not a stage in the life cycle of the Uromyces species on the same host. As additional evidence in support of this belief a recent observation is reported here.

In January last, while on a botanical excursion in the hills near Kolhapur (Radhanagari and Dajipore forests), it was found that in both these places *Jasminum malabaricum* plants were affected by the Uredo stage only; none of the plants showed any other stages nor even any traces of them in the form of dried spots of previous infection (as would be expected if the other stages indeed were present in the life history) on any part of their body.

This occurrence of the Uredo stage without being accompanied by the aecidial or teleuto stages confirms the belief that there are two distinct rusts on *Jasminum malabaricum*, one a Uromyces sp. occurring in the aecidial and teleuto stages and the other occurring only in the Uredo stage.

It is of interest here to record that a Uredo, also apparently unconnected with the *Uromyces hobsoni* occurring on *Jasminum grandiflorum* has been noted by Prof. Ajrekar at Matheran and Mt. Abu.

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*Ajrekar and Parandekar: Observations on *Uromyces* sp. on *Jasminum malabaricum* Wight and its relation to *Uromyces hobsoni* Vize. on *Jasminum grandiflorum* L. Journ. Ind. Bot. Soc. 1931, Vol. X, No. 3, p. 195.

REVIEW

HAMMOND, B. L. (1937) Development of *Podostemon ceratophyllum.* Bull. Torrey Bot. Club *64:* 17-36.

The only work on the embryo-sac of *Podostemon,* that we had so far, was that of MAGNUS (Flora, 1913) on *P. subulatus.* He reported that the embryo-sac is 4-nucleate and arises by two nuclear divisions of the lower dyad cell, resulting in 2 synergids, one egg cell and a single polar nucleus. Doubts have been expressed in recent years about the validity of his interpretations and the present paper by HAMMOND is therefore a welcome addition to our knowledge of the morphology of this interesting genus.

After describing the anatomy of the vegetative and reproductive organs, HAMMOND gives a well-illustrated account of the development of the embryo-sac in *P. ceratophyllum.* The hypodermal archesporial cell functions directly as the megaspore mother cell and divides to form 2 cells, of which the upper degenerates promptly. The nucleus in the lower cell divides to form the primary micropylar and primary chalazal nuclei, the last of which is much smaller from the very beginning and soon becomes unrecognisable. The primary micropylar nucleus undergoes two divisions to form a quartet which is responsible for the formation of the egg apparatus and upper polar nucleus.

It seems probable that *P. subulatus,* previously investigated by MAGNUS, will be found on reinvestigation to be similar to *P. ceratophyllum,* and that MAGNUS made the mistake of overlooking the primary chalazal nucleus completely. HAMMOND has proved its existence, even though it is ephemeral in nature. The development corresponds to that reported by WENT in several members of the Podostomaceae in a series of valuable papers.

The value of HAMMOND'S paper is slightly impaired by the fact that he makes no reference to the work of MAGNUS, and the customary " discussion" or comparison of his results with those of other workers is lacking.

P. MAHESHWARI.

The Journal of the Indian Botanical Society

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VOL. XVI DECEMBER, 1937 No. 6

CONTRIBUTIONS TO A SOUTH INDIAN MARINE ALGAL FLORA—II.

BY

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Communicated by M. O. P. Iyengar

Received for publication on 26th April 1937

This second contribution to a South Indian Marine Algal Flora deals with a series of species found when I continued my examination of Professor IYENGAR'S comprehensive collection of Algæ from South India. In the first part, I have dealt with the brown and red algæ only, and the same is the case in this part also, as Professor IYENGAR intends to work out the other groups himself.

In order to compare several of the Indian specimens with those found in J. AGARDH'S famous herbarium, several visits to Lund in Sweden were necessary, and I am very much indebted to Dr. HULTÉN, Keeper of the Herbarium of the Botanical Museum in Lund, for permitting me to work there. I am also very grateful to Professor H. KYLIN for valuable suggestions regarding critical species. I wish to thank him most sincerely for his kind hospitality during my repeated visits to Lund.

For the final determination of several difficult species I went to London in the spring of 1936 in order to study the different species found in the rich herbaria of the Royal Botanic Gardens, Kew, and of the British Museum (Natural History). I cannot thank the officials of these institutions sufficiently enough for all their kindness and help during my visits to their herbaria and libraries.

I am much indebted to the Trustees of THE CARLSBERG FOUNDATION for a grant towards the cost of the travel.

Copenhagen in April 1937.

PHÆOPHYCEÆ

I. Ectocarpales.

Fam. 1. Ectocarpaceæ.

Ectocarpus Lyngb.

1. **Ectocarpus breviarticulatus** J. Ag., Nya alger fraan Mexico (Öfversigt af K. Vetensk.-Akad. Förhandl. 15. Jan., 1847, p. 7). BOERGESEN, Mar. Alg. D. W. I., vol. I, p. 173, fig. 136, Copenhagen 1913-14. SETCHELL, American Samoa (Department of Marine Biology of the Carnegie Institution of Washington, vol. XX, 1924, p. 171, fig. 37).—*Ectocarpus hamatus* Cr., in MAZÉ et SCHRAMM, Essai de classif. Algues de la Guadeloupe, 2e Edit., 1870-77, p. 111. VICKERS, Phycologia Barbadensis, part II, pl. 29.

This characteristic species was at first found by LIEBMANN at St. Augustin on the pacific coast of Mexico, later on in the West Indies by MAZÉ and SCHRAMM, Mlle VICKERS and myself and finally by SETCHELL in American Samoa. Its occurrence at Madras, so far from its former areas of distribution is extremely interesting.

The plant from Madras Harbour was found "sticking to a stone in spray"—in surroundings quite similar to those of the West Indian plant—and formed low dense tufts about 2 cm. high. I compared it with the type material and found that it agreed very well with the original. The characteristic short roundish barrel-shaped plurilocular sporangia were about 55μ long and 45-50μ broad; the filaments had a breadth of 27-30μ. This species is also found at Mahabalipuram (The Seven Pagodas) south of Madras, which is a very exposed locality.

India: Madras Harbour, Sept. 1924, and Mahabalipuram, Jan. 1923, leg. M.O.P.I.

Distr.: West Indies, Mexico, American Samoa.

Fam. 2. Encoeliaceæ.

Colpomenia Derb. et Sol.

1. **Colpomenia sinuosa** (Roth) Derb. et Sol. Cfr. BOERGESEN, Some mar. Alg. Arabian Sea, p. 25.

Specimens with plurilocular sporangia are found in IYENGAR'S collection.

India: Tuticorin, 2nd Jan. 1928, leg. M. O. P. I.

Distr.: Widely spread in warm seas.

Chnoospora J. Ag.

1. **Chnoospora fastigiata** J. Ag., Spec. Alg. I, 1848, p. 171. BARTON, E. S., On the fruit of *Chnoospora fastigiata* J. Ag. in Journ. Linn. Soc. 33, 1897-8, p. 507, pl. 28.

var. PACIFICA J. Ag. 1-c. p. 172.

Several specimens are found in IYENGAR'S collection. One of these reached a height of about 25 cm. Others from the very exposed locality, " The Seven Pagodas," South of Madras, are only about 6-10 cm. high. The specimens had plurilocular sporangia.

India: The Seven Pagodas, January 1922, and Cape Comorin, Sept. 1924, leg. M. O. P. I.

Distr.: West Indies (var. ATLANTICA), Pacific Ocean, Japan, Australia, etc.

2. **Chnoospora implexa** (Her.) J. Ag., Spec., Alg. I, p. 172. WEBER, Algues du Siboga, p. 137.

A single dried specimen is found in IYENGAR'S collection ; it was not very suitable for anatomical examination, so I have not been able to see the sporangia.

The specimen seems to resemble those mentioned by Mme. Weber (1. c.) showing much likeness to KÜTZING'S figure in Tabulæ Phycologicæ, vol. IX, tab. 28, fig. 2 of *Dictyota obtusangula* (=*Chnoospora obtusangula* (Harv.) Sonder), a form most probably to be referred to *Ch. implexa;* compare Mme. WEBER, 1. c.

India: Tuticorin, 3rd Oct. 1923, leg. M. O. P. I.

Distr.: Red Sea, Malayan Archipelago, Japan, etc.

II. Dictyotales.

Fam. I. ***Dictyotaceæ.***

Spathoglossum Kütz.

1. **Spathoglossum asperum** J. Ag., Analecta Algologica, Continuatio I, 1894, p. 36. BOERGESEN, F., List mar. Alg. Bombay, p. 35, pl. 5.

Some specimens agreeing very well with those from Bombay as well as with specimens found in the British Museum (Nat.

Hist.), London, were collected by IYENGAR and myself in different places in India. In IYENGAR's collection one specimen from Krusadi Island has a thallus with very irregularly dentate and sinuate margins from which large and small proliferations are given out. A specimen from Tuticorin rather like this plant is found in the Herbarium of the British Museum.

India: Karvar, Bengi Bay, Febr. 1928 (!); Tuticorin, Febr. 1928, M.O.P.I., (!); Pearl Bed, March 1928, M. O. P. I. Cape Comorin, Sept. 1926, M. O. P. I. Krusadi Island, Pamban May 1929, M. O. P. I.

Distr.: Ceylon, India.

Zonaria J. Ag.

1. Zonaria variegata (Lamx.) Ag., Synopsis Alg., 1817, p. XX. For more literature compare BOERGESEN in Journ. Ind. Bot. Soc., vol. IX, 1930, p. 169.

India: Krusadi Island, Pamban, Oct. 1924, and Tuticorin, Oct. 1923, leg. M. O. P. I.

Distr.: Seems to occur in most warm seas.

2. Zonaria latissima Kütz., Tab. Phycol., vol. 9, p. 30, tab. 75, fig. 1.—Not *Zonaria Schimperi* (Ruch.) Kütz. to which species DE-TONI, Syll., III, p. 233, refers *Zonaria latissima* as a synonym though with a query.

A single but fine specimen in IYENGAR's collection agrees very well with KÜTZING's description. The plant is of a dark brown colour, 10 cm. high and about 13 cm. broad, flabelliform, deeply divided in several large and small lobes with attenuated-cuneate bases broadening abruptly near the middle into flabelliform or subreniform parts of variable breadth about 4-5 cm. broad with roundish even margins. The surface is concentrically zonate, and rather smooth, and the consistency firm and tough. The main stem is covered by brown rhizoids. A tangential transverse section of the reniform lobes shows that the thallus is composed of densely placed rows of cells containing about 9 cells in each row, these being about twice as broad as long with the exception of the cortical cells above and below which, being divided into two cells by vertical walls, are about as broad as long.

DE-TONI as said above refers *Zonaria latissima* to *Zonaria ? Schimperi* (Ruch.) Kütz., but the frond in this plant is described as "membranaceo-tenuissima" and KÜTZING's figures of the transverse sections of the thallus (Tab. Phycol., vol. 9, pl. 74) also show 4-5 cells with thin walls in the rows. A fine specimen of what I think to be *Zonaria Schimperi* from Ashrafi and Kaisum near the entrance of the Gulf of Suez in the Red Sea has been presented to me by a young Egyptian Algologist, Mr. A. H. NASR, during his stay in Copenhagen. It is a large plant about

20 cm. high and divided into several broad and narrow cuneate-subflabellate lobes. The thallus is thin, papery and brittle. It is of a yellowish brown colour with dark brown concentric zones formed at a distance of about 1 cm. between each zone. Kützing's figure quoted above is drawn from a defective specimen. As may be seen from the above description, this plant from the northern part of the Red Sea is quite different from *Zonaria latissima* Kütz.

In the Kew Herbarium, I saw a small specimen from Singapore which was determined by Setchell as *Zonaria latissima* Kütz. and which resembles the Indian plant very much. As regards the colour and the consistency of its thallus, *Zonaria latissima* Kütz. shows some likeness to *Zonaria nigrescens* Sonder from Australia, but the lobes in this species are more narrow.

India: Krusadi Island, leg. M. O. P. I. (no. 241), May, 1924.

Distr.: Red Sea, Singapore.

3. **Zonaria crenata** J. Ag., Till Algernes System., Lunds Univers. Aarsskr. t. IX, 1872, p. 48. Weber van Bosse, A., Algues Siboga, p. 175.

A single specimen preserved in formalin in Iyengar's collection is, I think, referable to this species. The Indian specimen, like the ones found by Mme. Weber in the Malayan Archipelago, resembles very much *Zonaria flava* (Clem.) Ag.

India: Tuticorin, Oct. 1924, leg. M. O. P. I.

Distr.: Malayan Archipelago, Australia.

Padina Adans.

1. **Padina tetrastromatica** Hauck, cfr. Boergesen in Journ. Ind. Bot. Soc., vol. IX, 1930, p. 172.

India: Tuticorin, 3rd Aug. 1923 and Cape Comorin, Sept. 1924, leg. M. O. P. I.

Distr.: Somaliland, Malayan Archipelago, Ceylon, India, China.

2. **Padina Commersonii** Bory. cfr. Boergesen, l.c., p. 170.

India: Krusadi Island, May 1924, leg. M. O. P. I.

Distr.: Arabian Sea, Malayan Archipelago, Ceylon, Mauritius, Tonga Island, Australia.

3. **Padina gymnospora** (Kütz.) Vickers, Liste Algues Barbade (Ann. Sc. Nat. Bot., Sér. 9. t. 1, 1905, p. 58); Phycologia Barbadensis, pl. VII. Boergesen, l.c., p. 170.

India: Pamban, Oct. 1921, leg. M. O. P. I.

Distr.: West Indies, Malayan Archipelago, India, Australia, etc.

Dictyopteris Lamx.

1. **Dictyopteris delicatula** Lamx. in Journ. Philom., 1809, no 20, tab. 6, fig. *B.*—*Haliseris delicatula* C. Ag., Spec., p. 144. J. AGARDH, Spec., Alg., vol. I, p. 116. KÜTZING, Tab. Phycol., vol. IX, pl. 56, fig. 1.

Several specimens are to be found in IYENGAR'S collection.

India: Tuticorin, Febr. 1928, M. O. P. I., (!); Cape Comorin, Oct. 1924, M. O. P. I.; Pamban, 1921, M. O. P. I.

Distr.: West Indies, Brazil, Malayan Archipelago.

1. **Dictyopteris Woodwardii** (Brown) J. Ag., Spec. I, p. 116. KÜTZING, Tab. Phyc., vol. IX, tab. 53, fig. II. *Fucus Woodwardii* Brown in TURNER, Fuci, tab. 158.

From Malvan I have seen a fruiting specimen which had the dentate margin characteristic of this species. The groups of hairs in the young parts of the thallus are found in a row on both sides of the midrib at a distance of about 1/3 of the breadth of half of the lamina; this is also easily seen in TURNER'S fine figure. The fructiferous organs form a narrow belt close to the midrib on both sides of it.

To this species is referable too, in my opinion, a specimen from Krusadi Island in South India. Its margin is undulating and provided with teeth and the groups of hairs are arranged in the same way as in the specimen mentioned above. It is sterile.

India: Malvan, March 15, 1928, leg. S. C. DIXIT. Krusadi Island, Sandy Point, March 1928, leg. M. O. P. I.

Distr.: Australia, China.

3. **Dictyopteris Muelleri** (Sond.) Web. v. Bosse, Algues Siboga, p. 181.—*Haliseris Muelleri* Sonder in Linnæa, vol. 25, p. 665. J. AGARDH, Till Alg. System. V, p. 132. HARVEY, Phycol. austr., tab. 180. KÜTZING, Tab. Phyc., vol. 9, tab. 56, I.

Two small sterile specimens appear to be referable to this species. As regards the ramification and shape of the frond, they agree very well with KÜTZING'S figure and have the small groups of hairs scattered over the whole surface of the thallus. But as they are young and sterile, the determination is of course not quite certain. Mme. WEBER found some sterile specimens in the Malayan Archipelago.

India: Tuticorin, dredged near Hare Island in about 2-4 fathoms of dirty water, 1-3-1928, (!).

Distr.: Australia, Malayan Archipelago.

Dictyota Lamx.

1. **Dictyota maxima** Zan., Phycearum indicarum pugillus in Memor. del. R. Istituto, vol. XVII, Venetiis 1872, p. 4, no 12, pl. I, fig. 1-3.

I have not been able to compare my specimens with authentic material, but in the Kew Herbarium I have seen some specimens from Ceylon referred to this species, and they resemble mine very much.

In a small collection of algæ from South India collected by DR. E. K. JANAKI AMMAL and DR. C. E. ERLANSON and sent to me for determination by Professor W. R. TAYLOR, Ann Arbor, Michigan, I found a large fine specimen which I think is referable to this species. It agrees very well with the description and figure given by ZANARDINI. It differs only in one respect. The margins are more or less provided with small teeth. The specimen is fertile, the tetrasporangia being spread over the whole thallus.

India: Tuticorin dredged at 3-4 fathoms of water near Hare Island (!); Karvar: Bengi Bay, (!); Krusadi Island 23-6-1932, leg. E. K. JANAKI AMMAL.

Distr.: Sarawak.

III. Fucales.

Fam. 1. ***Fucaceæ.***

Hormophysa Kütz.

1. **Hormophysa triquetra** (L.) Kütz., Phycologia generalis, p. 359. SETCHELL, W. A., Some marine plants from South Eastern Melanesia (Proceedings of the California Academy of Sciences, 4th series, vol. 21, 1935, p. 264).—*Fucus articulatus* Forssk., Flora Ægpyptiaco-Arabica, p. 191. For more synonyms compare DE-TONI, Sylloge Algarum, vol. III, p. 176: *Cystoseira triquetra, Cystoseira prolifera* and *Cystoseira latifrons* and p. 188: *Hormosira? articulata.*

The synonymy of this species is very complicated, due evidently to the investigators having had only very poor material. Thus the type-specimen of *Fucus articulatus* found in FORSSKAAL's herbarium in the Botanical Museum, Copenhagen, is a small fragmentary piece composed only of seriated vesicles in agreement with the specific name of FORSSKAAL. The specimen was evidently lying near the shore for some time, where it must have been battered about and worn and bleached. Because of this and because, when working out our FORSSKAAL's algæ, I was quite without suitable material to compare it with, I gave up the determination and allowed it to retain the name it has in Sylloge Algarum[1]. But last winter, in Professor IYENGAR's collection, I came across some well preserved specimens of *Hormophysa triquetra*, and, while examining these, my attention was once more turned to FORSSKAAL's plant. Therefore, when some time after, in the spring of 1936, I visited the British Museum (Nat. Hist.), London, where I knew that some of FORSSKAAL's algæ are kept, I asked Dr. TANDY if a specimen of *Fucus articulatus* was to be found there. There was a specimen in the Museum! The specimen was much larger and more complete than the one found in Copenhagen, so that there was no doubt at all about its belonging to *Hormophysa*. But as of course it would be of much interest to find in the Red Sea some specimens showing a likeness to the fragment found in Herb. FORSSKAAL, I asked Mr. NASR during his stay here in Copenhagen, to send me some material of *Hormophysa* and especially to try to find some specimens resembling the one from which the fragment in FORSSKAAL's herbarium must be presumed to have originated. Mr. NASR, most kindly sent me several specimens of various shapes: one broad form resembling KÜTZING's figures in Tabulæ Phycologicæ, vol. X, pl. 60, II and pl. 61, named *Hormophysa latifrons* and *Hormophysa articulata* respectively and a narrow-leaved one resembling KÜTZING's figure of *Hormophysa triquetra* on pl. 60, I. The last mentioned slender form has often long rows of vesicles in the upper branches, and when a piece of such a specimen is cast ashore and worn by the waves it will certainly become quite like FORSSKAAL's specimen.

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[1] BOERGESEN, F., A revision of FORSSKAAL's Algæ, etc. in Dansk Botanisk Arkiv, vol. 8, 1932, Nr. 2, p. 11.

The Indian specimens in IYENGAR's collection resemble in shape KÜTZING's figures pl. 60, II and pl. 61 named *Hormophysa latifrons* and *H. articulata* respectively. But, as pointed out by Mme. WEBER, Algues Siboga, p. 148, these two species are identical and are, as done by SETCHELL (l.c.), to be considered broad-leaved forms of *Hormophysa triquetra* (L.) Kütz. (=*Fucus triqueter* L.) which species also includes *Fucus articulatus* Forssk.

India: Krusadi Island, Pamban, 24th Apr. 1924, leg. M.O.P.I.

Distr.: Red Sea, Malayan Archipelago, Australia, etc.

Cystophyllum J. Ag.

1. Cystophyllum muricatum (Turn.) J. Ag., Spec. Alg. I, p. 231.—*Fucus muricatus*, Turner, Fuci, p. 107, pl. 112. For more literature comp. DE-TONI, Syll. Alg., III, p. 154.

India: Krusadi Island, Pamban, May 1924 and October 1924, leg. M.O.P.I.

Distr.: Persian Bay, Arabian Sea, South India, Malayan Archipelago, Australia.

RHODOPHYCEÆ

A. Bangiales.

Fam. 1. Bangiaceæ.

Porphyra C. Agardh.

1. **Porphyra tenera** Kjellm. Japanske Arter af Slägtet *Porphyra*, p. 20, tab. I, fig. 6; tab. 4, figs. 2-5; tab. 5, figs. 22-26. YENDO, Notes on Algæ new to Japan IV, p. 52-4 (in Bot. Mag. 30). ISHIKAWA, Cytological studies on *Porphyra tenera* (Bot. Mag., 35, p. 206, pl. IV). OKAMURA, ONDA and HIGASHI, Preliminary notes on the development of the carpospores of *Porphyra tenera* Kjellm. (Bot. Mag. 34, p. 131). C. K. TSENG, Economic seaweeds of Kvantung Province. S. China (Lingnan Science Journ , vol. 14, 1935, p. 99, pl. 1, fig. 2).

Some dried specimens in IYENGAR's collection seem to be referable to this species. I have been able to compare the Indian plant with some Japanese ones from Goi, prov. Kazusa, collected by YAMADA and with these the Indian ones agree very well. The specimens are elongated linear with broad bases reaching a length of about 25 cm. and with sinuated undulated margins. They agree quite well with TSENG's above quoted figure. The colour is greyish-purple. In the upper ends some of the specimens were fructiferous. The thallus is thin and adheres well to paper.

India: Madras Harbour, January 18th 1926, leg. M.O.P.I.

Distr.: Japan, China.

Erythrocladia Rosenv.

1. **Erythrocladia subintegra** Rosenv., Mar. Alg. of Denm. Vol. I, Rhodophyceæ, p. 73, figs. 13-14. BOERGESEN, Mar. Alg. D.W.I., vol. II, p. 7, figs. 3-4. KYLIN, Mar. Red Algæ vicinity Biol. Station at Friday Harbor, Wash. (Lunds Univ. Aarsskrift; N.F. Avd. 2, Bd. 21, nr. 9, 1925, p. 9, fig. 3 c-g.)

Well developed specimens with sporangia were found upon *Chætomorpha media*.

India: Mahabalipuram (The Seven Pagodas) South of Madras, Jan. 1923, leg. M.O.P.I.

Distr.: Seems to be widely spread.

B. Florideæ.

I. Nemalionales.

Fam. 1. **Helminthocladiaceæ.**

Sub-fam. 1. **Nemalieæ.**

Liagora Lamx.

Liagora ceranoides Lamx., Hist. Polyp. corallig. flex., 1816, p. 239. Howe, M. A., Algæ, in Britton and Millspough. The Bahama Flora, p. 555, 1920. Boergesen, F., Algæ from the Canary Islands, p. 58, 1927.—*Liagora pulverulenta* Ag., Spec. Alg., vol. I, 1821, p. 396. Boergesen, F., Mar. Alg. D.W.I., vol. II, p. 80-85, figs. 87-92.

A few specimens are found in Iyengar's collection. The cystocarps agreed very well with my figure 90 d in the paper quoted above. Only a few carpogonial branches were found in the material. They were not so much curved as in the West Indian plant.

India: Mandapam, Oct. 1925, leg. M.O.P.I.

Distr.: India, Malayan Archipelago, Red Sea, West Indies, etc.

Sub-fam. 2. **Dermonemeæ.**

Dermonema (Grev.) Schmitz.

1. **Dormonema gracile** (Mart.) Schmitz, in Heydrich, Algenfl. Ost-Asien (Hedwigia, 33, 1894, p. 289). Weber van Bosse, Alg. Siboga, p. 204.—*Gymnophloea gracilis* Martens, Tange d. Preuss. Exp. n. Ost-Asien, 1866, p. 146. Kützing, Tab. Phycol. vol. 17, tab. 1 (Kützing says that his plant is from "Nova Caledonia." As pointed out by Mme. Weber, this is a mistake; the specimen in his herbarium originates from Galle, Ceylon). *Dermonema dichotomum* Harv., Alg. Ceyl. no 93. Heydrich l. c.

Heydrich l. c. gives a description of the plant accompanied by some figures. In the material examined by me I found only the carpogonial branch; it is composed of 3 cells.

The gonimoblastic filaments described by Schmitz in Engler und Prantl, Nat. Pflanzenf. I, 2, p. 335, fig. 205, were not found.

The plant was quite infected with *Ectocarpus Dermonematis*.

India.: Cape Comorin, Sept. 1924, leg M.O.P.I.

Distr.: Ceylon, Formosa, N. Guinea.

Fam. 2. **Chætangiaceæ.**

Actinotrichia Decsne.

1. **Actinotrichia fragilis** (Forssk.) Boergs., A revision of Forsskaal's Algæ (Dansk Bot. Arkiv, Bd. 8, 1932, p. 6., pl. I, fig. 4)—*Fucus fragilis* Forssk., l.c., p. 190. *Actinotrichia rigida* (Lamx.) Decsne, Sur les Corallines in Ann. sc. nat., II sér., Bot., vol. 18, 1842, p. 118.

Some small specimens are found in Iyengar's collection.

India: Krusadi Island, Pamban, April 1924 and May 2, 1926, leg. M. O. P. I.

Distr.: Red Sea, Indian and Pacific Oceans.

II. Gelidiales.

Fam. 1. **Gelidiaceæ.**

Gelidiopsis Schmitz.

1. **Gelidiopsis variabilis** (Grev.) Schmitz in Engler's Bot. Jahrb., vol. 21, 1895-6, p. 148. Feldmann, J. in Recueil de Travaux Cryptogamiques dédiés à Louis Mangin, Paris 1931, p. 156.—*Gelidium variabile* (Grev.) J. Ag., Spec. Alg., II, p. 468. Kützing, Tab. Phyc., vol. 19, tab. 23 c.d. *Gigartina variabilis* Grev. mscr. in Hb. Hookeri.

The Indian plant looks very much like Harvey's specimen in his Ceylon Algæ exsicc. no 33, and also agrees very well with Kützing's figure quoted above, only it is somewhat smaller. A transverse section of both Harvey's and of the Indian plant (dried material) shows the circumference to be oval, indicating that the thallus most probably is not quite terete but somewhat compressed.

India: Cape Comorin, Sept. 1924 and Karwar, Febr. 1928, leg. M. O. P. I.

Distr.: Indian Ocean.

2. **Gelidiopsis repens** (Kütz.) Schmitz in Engler's Bot. Jahrb., XVI, 1895, p. 148. Weber van Bosse, Alg. Siboga, p.425.—*Gelidium repens* Kütz., Tab. Phycol., Vol. 18, 1868, pl. 60. *Gelidium acrocarpum* Harv., Alg. Ceylon no 34 (nomen nudum). Kützing, Tab. Phycol., vol. 19, 1869, pl. 23. J. Agardh, Spec. Alg. vol. III, 1876, p. 552.

A single specimen is found in Iyengar's collection. It shows the very characteristic feature of this species as pointed out in Agardh's description: in the upwardly flattened and dichotomous-flabellate thallus; the apices of the segments are either broadly rounded or acute. I have compared the Indian specimen with Harvey's above mentioned one from Ceylon as well as with some specimens collected by me near Galle.

India: Tuticorin, March 3rd, 1928, leg. M. O. P. I.

Distr.: Indian and Pacific Oceans.

III. Cryptonemiales.

Fam. 1. ***Rhizophyllidaceæ.***

Chondrococcus Kütz.

1. **Chondrococcus Hornemanni** (Mert.) Schmitz in ENGLER Bot. Jahrb. XXI, p. 170 (1895). BOERGESEN in Kew Bull. 1933, no 3, p. 117.—*Fucus Hornemanni* Mert., in Göttinger Gel. Anzeiger, no 64 (1815). *Desmia Hornemanni* Lyngb., Hydrophytolog. Dan. p. 35, tab. 7 C, 1819.

Tetrasporic specimens were found in IYENGAR's collection. The sporangia form irregularly shaped expansions on the lobes of the thallus. They are divided transversely by oblique walls.

India: Tuticorin, Cape Comorin, Pamban, leg. M. O. P. I.

Distr.: Indian Ocean.

Fam. 2. ***Corallinaceæ.***

Amphiroa Lamx.

1. **Amphiroa anceps** (Lamk.) Decne., Sur les Corallines (Ann. Sc. Nat. 2 sér., Bot., t. 18, p. 125). Harvey, Nereis Australis, p. 98, tab. 37. WEBER VAN BOSSE and M. FOSLIE, The Corallinaceæ of the Siboga Exp., p. 93.—*Corallina anceps* Lamk., Mém. du Muséum, p. 238 (1815).

A form resembling very much HARVEY's figure quoted above is found in a collection of Indian Algæ belonging to the British Museum and in IYENGAR's collection preserved in formalin. The uppermost joints are thin and almost cylindrical.

India: Cape Comorin, Sept. 1920 and Oct. 1924, leg. M. O. P. I.

Distr.: India, South Africa, Malayan Archipelago, Japan, West Australia.

Fam. 3. **Grateloupiaceæ.**

Corynomorpha J. Ag.

1. Corynomorpha prismatica J. Ag., Florideernes Systematik, 1870 (Lunds Univ. Aarsskr. VIII) p. 3-4. Epicrisis, p. 142-3.—*Acrotylus prismaticus* J. Ag., Spec. II, p. 193. *Dumontia prismatica* J. Ag., Symbolæ in Linnæa, 15, p. 19. *Gymnophloea prismatica* Kütz., Spec. Alg., p. 711 ; Tab. Phycol., vol. 16, pl. 58.

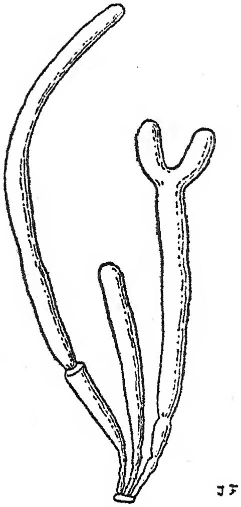

Fig. 1.—*Corynomorpha prismatica* J. Ag. Some young specimens. Natural size.

Only a few sterile specimens are found in Iyengar's collection. The plant grows in dense tufts, small young specimens being developed from the basal disc. The largest specimen was about 7 cm. high. One of the larger specimens had several concentric swellings near the base ; I presume that the plant is perennial and that these swellings are due to the fact that during the unfavourable season of the year the plant dies down to its base and recommences its growth, when conditions become more favourable. In one specimen two filaments were developed from such a swelling. In the dêscription of the plant, it is said: "Frondes simplicissimæ," but, besides the above mentioned specimen, I have seen in the British Museum in London a specimen of Ferguson's Alg. Ceylon without any number and undetermined but quite like the Indian plant. Several of the specimens in this collection were divided. (Compare also Fig. 1.)

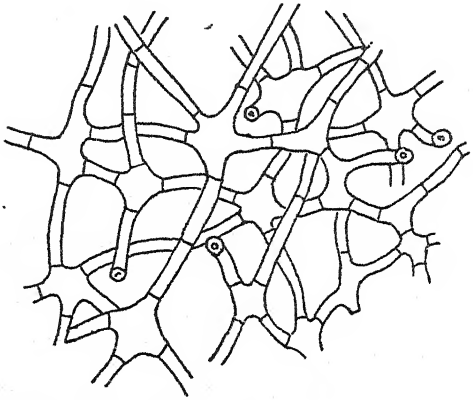

Fig. 2.—*Corynomorpha prismatica* J. Ag. Transverse section of medullary layer showing stellate cells. × 400.

A transverse section of the thallus of a specimen preserved in formalin shows that the interior of the thallus is composed of a very fine tissue of stellate cells forming larger meshes in the middle of the thallus and smaller ones towards the periphery (Fig. 2). This tissue is surrounded by a cortical layer which is composed of dichotomously divided short filaments, the cells of which become smaller and oblong at the periphery, where they are placed very close together.

India: Cape Comorin, Sept. 1924, leg. M. O. P. I.

Distr.: India, Ceylon, East Africa.

Cryptonemia J. Ag.

1. **Cryptonemia Lomation** (Bertol.) J. Ag., Spec. Alg. vol. II, p. 227 ; Epicr. p. 165. Hauck, Meeresalgen, p. 130. Weber van Bosse, Algues Siboga, p. 248.—*Fucus Lomation* Bertolini, Opusc. Bol. II, p. 289, t. 10, fig. 3 (after De-Toni); Amoenitates Italicæ, 1819, p. 289, tab. 4, fig. 3. *Euhymenia Lactuca* Kütz., Spec. Alg., p. 741 ; Tab. Phycol. XVII, tab. 71.

A few specimens belonging to Iyengar's collection and preserved in formalin seem referable to this species. The specimens are sterile about 3—4 cm. high with no central nerve. Most of the new leaves are given out from the edges of the older ones, but some also from the base of the former leaf as found by Mme. Weber, l. c. The thallus is about 100 μ thick. The larger specimens are rather like Kützing's figure quoted above.

India: Krusadi Island, 28th April 1924, "sticking to corals", M. O. P. I.

Distr.: Mediterranean Sea, Malayan Archipelago.

2. **Cryptonemia coriacea** Schmitz, Mar. Florideen von Deutsch-Ostafrika (ENGLER's Bot. Jahrb., 21, 1895, p. 166).

Although I have never seen any type-specimen of this species and know it only from SCHMITZ's description, I assume some small specimens in IYENGAR's collection to be most probably referable to this species.

After a fresh examination, I believe that the very large specimens from Karachi which, in Kew Bulletin 1932, p. 127, I have referred to *Cryptonemia undulata* Sonder also belongs most certainly to SCHMITZ's species, since they agree with his description. But, as mentioned above, I have not been able to compare the specimens with authentic material. On the other hand, the specimens from Dwarka and Okha Port mentioned also in the same number of the Kew Bulletin are a much smaller, more delicate plant with a very much undulated thallus and resembling so very much KÜTZING's figure in Tab. Phycologicae vol. 19, tab. 31, that I think it is quite right to refer them to SONDER's species.

India: Cape Comorin, Sept. 1924, leg. M. O. P. I.

Distr.: Kikogwe (East Africa), Karachi.

Carpopeltis Schmitz.

1. **Carpopeltis rigida** (Harv.) Schmitz in ENGLER's Bot. Jahrb., 26, 1895, p. 157. WEBER v. BOSSE, Alg. Siboga, p. 246, OKAMURA, Icones Jap. Algae, vol. II, p. 63, pl. 66.—*Cryptonemia rigida* Harv., Alg. Ceylon no 51.

A cystocarpic specimen is found in IYENGAR's collection.

India: Tuticorin, March 1928, M. O. P. I.

Distr.: East Coast of Africa, Ceylon, Malayan Archipelago, Japan.

IV. Gigartinales.

Fam. 1. ***Solieriaceæ.***

Solieria J. Ag.

1. **Solieria robusta** (Grev.) Kylin, Florideenordnung *Gigartinales*. (Lunds Universitets Aarsskrift., N. F., Avd. 2, Bd. 28, 1932, p. 18).—*Rhabdonia robusta* J. Agardh, Spec. Alg. 2, 355. BOERGESEN, in Kew Bulletin, 1934, p. 10.

forma WIGHTII J. Agardh, 1. c., p. 355. KYLIN, 1. c., p. 20, tab. 5, fig. 10.

A single specimen is found in IYENGAR's collection.

India: Tuticorin, Pearl Bed, March 2nd 1928, leg. M. O. P. I.

Distr.: Australia, Japan, Malayan Archipelago.

Sarconema Zanard.

1. **Sarconema indicum** (J. Ag.) Kylin, Die Florideenordnung *Gigartinales* (Lunds Universitets Aarsskrift, N. F. Avd. 2, Bd. 28, no 8, Lund 1932, p. 22, tab. 8, fig. 17).—*Solieria indica* J. Ag., Spec. Alg., p. 723.

A small sterile specimen agreeing very well with the original specimen in J. Agardh's herbarium according to Kylin's figure is found in Iyengar's collection.

India: Cape Comorin, Sept. 1920, leg. M. O. P. I.

Distr.: India.

Fam. 2. *Hypneaceæ.*

Hypnea Lamx.

1. **Hypnea pannosa** J. Ag., Alg. Liebm., p. 14; Spec. Alg., II, p. 453; Epicrisis, p. 565. Kützing, Tab. Phyc. vol. XVIII, tab. 27.

I compared the Indian specimen with Liebmann's original material determined by J. Agardh, and found that they agreed very well, only the thallus of the Indian plant was a little broader. Specimens with tetrasporangia were found in February.

India: Karvar, Febr. 1928, (!); Tuticorin, Febr. 1928, (!); Cape Comorin, Oct. 1924, leg., M. O. P. I.

Distr.: Pacific and Indian Oceans.

Fam. 3. *Sarcodiaceæ.*

Sarcodia J. Ag.

1. **Sarcodia ceylonensis** (J. Ag.) Kylin, Die Florideenordnung *Gigartinales* (Lund's Universitets Aarsskrift. N. F., Avd. 2, vol. 28, no 8, p. 56, pl. 21, fig. 52).—*Carpococcus ceylonensis* J. Ag., Analecta Algologica, Contin. V, 1899, p. 46.

The female but fragmentary specimens seen by me seem to agree perfectly well with Kylin's above quoted figure of the original specimens in Agardh's Herbarium. The plant has a thick very irregularly shaped thallus along the margins and on the flat sides of which the cystocarps are developed in great profusion. The cystocarps protrude much and are subglobular in shape. As mentioned by Kylin, a transverse section of a cystocarp does not show a large fused cell. In the middle of the gonimoblasts a tissue of small cells is found.

The anatomy of the thallus agrees very well with that of *Sarcodia ceylanica*. At the periphery is found a cortical layer of very small cells arranged in vertical rows and below this is a tissue of cells growing larger and stellate inwards. In the middle there is a medullary tissue of filaments.

India: Cape Comorin, Oct. 1924, leg. M. O. P. I.

Distr.: Ceylon.

Fam. 4. ***Gracilariaceæ.***

Gracilaria. Grev.

1. Gracilaria lichenoides (L.) Harv. in Lond. Journ. III, p. 445. J. AGARDH, Spec. Alg. II, p. 588; Epicrisis p. 412. TURNER, Fuci, tab. 118.

Compared with the small peripheral cells, the cells of the medullary tissue are very large which is the characteristic feature of this plant and which makes the thallus collapse when dried.

The appearance and ramification of the Indian plants resemble to a great degree TURNER's figure quoted above. The cystocarps are scattered, much protruded and semi-globose.

India: Tuticorin, 29th February 1928 (!), M. O. P. I. Krusadi Island, Pamban, Oct. 1922, M. O. P. I.

Distr.: Indian and Pacific Oceans.

2. Gracilaria pygmæa nov. sp. Frons nana, ca. 4 cm. alta, plana, linearis, subcartilaginea, fastigiata, irregulariter dichotoma vel polytoma. Thallus ca $\frac{3}{4}$-$1\frac{1}{4}$ mm. latus et ca 400 μ crassus. Cystocarpia per totam frondem sparsa.

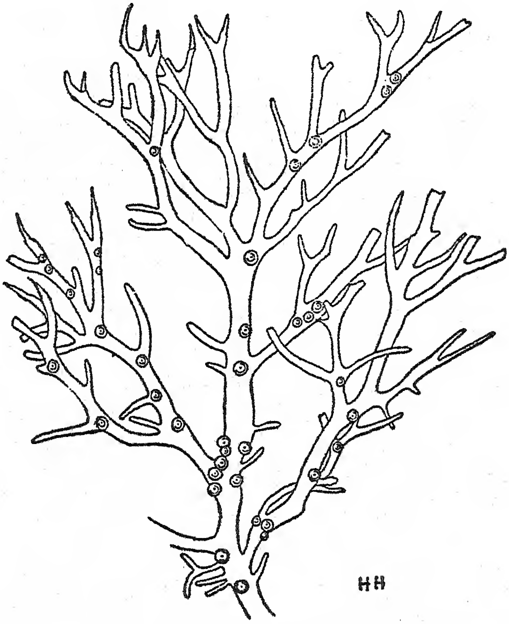

Fig. 3.—*Gracilaria pygmæa* Boergs. Habit of a female plant. × 3.

India: Krusadi Island, April 1924, leg. M. O. P. I.

This fine little *Gracilaria* (Fig. 3) forms a much ramified low tuft about 4 cm. high. The thallus is irregularly divided from near the base. The branches are given out from the edges of the flat thallus either alternately or 2-3 seriately from the same side, the upper parts thus getting an antler-like appearance. The thallus is about $\frac{3}{4}$-1$\frac{1}{4}$ mm. broad and about 400 μ thick. Only a female specimen was found. The cystocarps occur scattered on the flat side of the thallus, and are semispherical in shape and protrude much. Fig. 4 shows a transverse section of a ripe cystocarp with the parenchymatous tissue in the middle so characteristic of *Gracilaria.* The transverse section of the thallus is that generally found in *Gracilaria* with a medullary tissue composed of large roundish cells covered by a thin layer of small cortical cells. The large cells have a diameter of about 100 μ. On account of its small size this plant is easily distinguished from all hitherto known species.

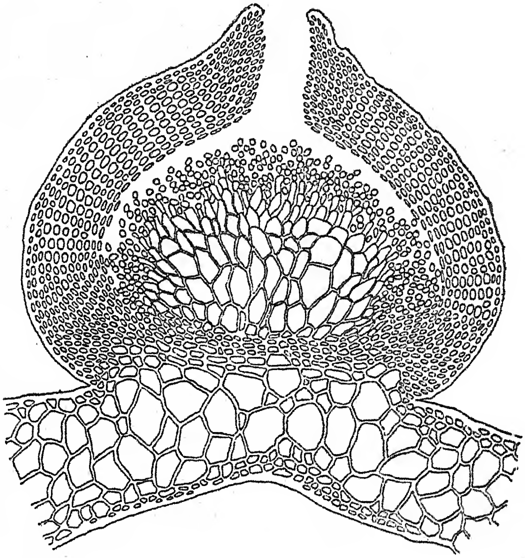

Fig. 4.—*Gracilaria pygmæa* Boergs. Transverse section of a cystocarp. × 50.

Corallopsis Grev.

Corallopsis opuntia J. Ag., Epicrisis, p. 409.—*Corallopsis cacalia*? Harvey, Alg. Ceylon no. 30.

In a paper on Ceylon marine Algæ (in the Ceylon Journal of Science, Section A, Botany, vol. XII, part 2, Colombo 1936, p. 86) I have referred some material resembling Harvey's plant no. 30 to *Gracilaria crassa* (Harv.) J. Ag. I did so because I had collected the material together with *Gracilaria crassa* in the same locality. And, when I collected it, I was of opinion that it belonged to *Gracilaria crassa,* the somewhat thinner and more irregularly developed thallus of the specimens being due to the fact that these specimens were growing a little outside the optimum for the occurrence of this species. This supposition is quite probably correct. But, in order to be certain about it, a fresh examination is necessary. And, as in my Indian material I have now some material agreeing with HARVEY'S specimens of *Corallopsis opuntia* J. Ag. (Ceylon Alg. no 30) but not resembling *Gracilaria crassa,* I prefer to call them as I have done above.* I do so also because I have received from DR. C. K. TSENG, Shantung, China, two small specimens of a related form which have more regularly articulated thalli. These specimens seem to be quite like a plant which Mme. WEBER, in Algues de I' Expétition danoise aux Iles Kei (Vidensk. Medd. fra Dansk naturh Forening, Bd. 81, 1926, p. 145) refers to *Corallopsis Salicornia* var. *minor* Sond. according to the fine material found here in the Botanical Museum. In the lowermost part of these specimens the thallus is more or less cylindrical but higher up is much articulated. They seem to grow quite in the same manner as *Gracilaria crassa* and *Corallopsis opuntia* having arch-shaped, downwardly bent branches which when they touch rocks or other suitable substrata become fixed to these thus forming firm, dense cushions on the rocks. I feel much inclined to consider both DR. TSENG'S specimens and those from the Kei Island to be more articulated and better developed specimens of *Corallopsis opuntia* than those collected by HARVEY (Ceyl. Alg. no 30) on which J. AGARDH based this species.

India: Tuticorin.

Distr.: Ceylon, Malayan Archipelago.

Fam. 5. **Phyllophoraceæ.**

Gymnogongrus Mart.

1. **Gymnogongrus pygmæus** (Grev.) J. Ag., Spec. Alg., II, p. 317; Epicrisis, p. 209. KÜTZING, Tab. Phyc., vol. XIX, tab. 64.—*Chondrus pygmæus* Grev., M. S. in Hb. HOOKER.

Female specimens were gathered by IYENGAR in February.

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*During a visit to Lund I was able to examine the specimens of HARVEY'S Ceylon Alg. no 30 found in J. AGARDH'S Herbarium. Three specimens are found. Two of these are quite like the one found in the Botanical Museum, Copenhagen, the lower part of the thallus being more or less cylindrical and subdichotomously divided, having higher up here and there an articulated pear-like thallus. The third specimen (also no 30) is a bleached specimen which most probably had been cast ashore. Its thallus is somewhat more robust. The lower parts of the thallus are cylindrical, on which some pear-like segments occur, these again being crowned by some flat prolongations.

The cystocarps form protuberances on the thallus ; they are proportionally large with a great number of carpospores arranged in groups surrounded by rhizoid-like filaments imbedded in slime.

India: Tuticorin, Hare Island, Cape Comorin, leg. M.O.P.I

Distr.: India, Ceylon, Japan.

V. Rhodymeniales.

Fam. 1. ***Champiaceæ.***

Champia Desvaux.

1. Champia parvula (Ag.) Harv., Nereis Bor. Am., vol. II, p. 76.—*Chondria parvula* Ag., Systema algarum, p. 207.

Some sterile specimens are found in IYENGAR's collection. Breadth of the filaments ca 1 mm.

India: Tuticorin (Hare Island), March 1928, leg. M.O.P.I., (!); Krusadi Island, Pamban, Oct. 1924, leg. M. O. P. I.

Distr.: Most warm seas.

2. Champia globulifera nov. spec.

Frons caespitosa, ca 6 cm. alta et ultra (?), cylindracea, articulata et moniliformis, paniculatim ramosa. Rami oppositi aut verticillati aut singuli, ad basin contracti ad apicem versus leniter attenuati, apicibus obtusi, novos ramulos emittentes. Thallus in ramis principalibus ca 2 mm., in ramulis ca $1\frac{1}{4}$-$1\frac{1}{2}$ mm. latus, in sectione transversale ex stratis duobus cellularum compositus. Articuli ventricosi, diametro subaequales aut in superiore parte ramorum paullulum breviores.

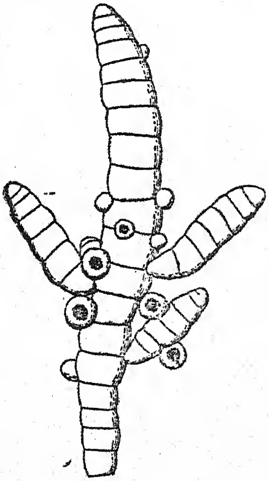

Fig. 5.—*Champia globulifera* Boergs. Part of a female plant with cystocarps. × 5.

Cystocarpia globose-urceolata, permagna, ca 1 mm. longa et lata in ramis ramulisque sparsa. Tetrasporangia in ramis sparsa.

India: Pamban, Oct. 1924, leg. M. O. P. I.

The largest specimens seen by me reach a height of about 6 cm. The plant forms dense tufts, as several shoots issue from the basal disc, and decumbent branches are able to form new discs, thus giving rise to new tufts (Fig. 6). The plant is monopodial in growth, and the branches are given out in all directions. They are either solitary or often opposite or verticillate, and they are ramified again in the same way but to a less extent. The main shoots reach a breadth of about 2 mm., but the branches are a little less broad. The branches are narrowed at their base and taper slowly towards their upper ends. The apex is obtuse. The plant is clearly constricted at the diaphragms, the segments becoming barrel-shaped and about as long as broad, but becoming gradually shorter upwards (Fig. 5).

A transverse section (Fig. 7 c) shows that the wall is composed of two layers of cells, the large cells of the wall becoming covered more or less completely by a cortical layer composed of rather large cells.

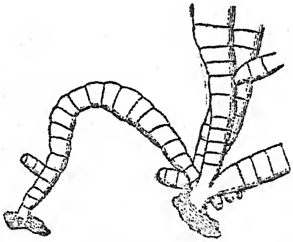

Fig. 6.—*Champia globulifera* Boergs. Base of a plant. Compare the text. × 4.

The cystocarps are nearly globose (Fig. 7a.) and rather large and measure about 1 mm. long and 1 mm. broad. They occur scattered on the thallus though often with a tendency to place themselves in small groups round the constrictions. The tetrasporangia are found scattered in the walls of the branches.

The Indian plant in size and shape appears to be related to the West Indian *Champia salicornoides*, but, when examined more carefully, several characters are found by means of which it can be distinguished from the latter. Thus the wall in the West Indian plant (at any rate in the plant I have referred to *Champia salicornoides*, compare my description in Mar. Alg. D. W. I., vol. II, p. 409, figs. 393-4) has only one layer of large cells. Another character is the shape of the cystocarps which in *Champia salicornoides* are elongated urceolate becoming much narrowed upwards. The figure (Fig. 7b) shows such a cystocarp; it is 915μ long, 858μ broad and upwards only 286μ.

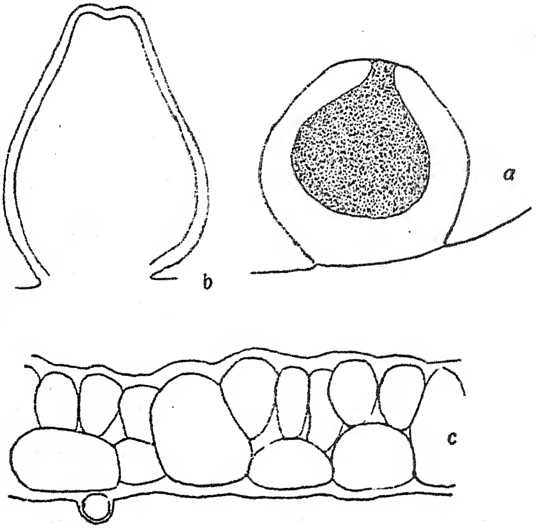

Fig. 7.—*a*, cystocarp of *Champia globulifera* Boergs. *b*, cystocarp of *Champia salicornoides* Harv.; *c*, transverse section of the wall of *Champia globulifera*. *a* and *b*. × 35; *c*. × 200.

The Indian plant seems also to show much likeness to *Champia Kotschyana* Endl. et Dies., a plant which I only knew from descriptions. The latter agrees with *Champia globulifera* in having globose cystocarps, but if Kützing's figures (Tab. Phycol., vol. 15, pl. 91, figs. a, b) give a correct picture of the plant, its articulations are much shorter and it does not seem to be so densely branched as *Champia globulifera*. Of how many layers of cells the wall is built is not mentioned in the description.

3. **Champia compressa** Harv., The genera of South African Plants, Cape Town 1838, p. 402; Nereis Australis, London 1847, p. 78, tab. XXX. J. Agardh, Spec., Alg., p. 370; Epicrisis, p. 305. For more literature and synonyms, see De-Toni vol. IV, p. 561.

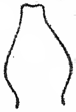

Fig. 8.—*Champia compressa* Harv. Outline of a cystocarp. × 12.

Of this fine plant I have collected several tetrasporic specimens. The tetrasporangia are formed over the whole surface. In Iyengar's collection a few dried female specimens are found. Fig. 8 shows the outline of a cystocarp; their shape agrees very well with HARVEY's figure. The cystocarp figured was 1. 4 mm. long and 1 mm. broad.

India: Tuticorin, Hare Island, 29th February 1928, leg. M. O. P. I.

Distr.: Cape, Newcaledonia, Ceylon, Friendly Islands, Borneo, etc.

Fam. 2. ***Rhodymeniaceæ.***

Sub-fam. 1. ***Rhodymenieæ.***

Coelarthrum Boergs.

1. **Coelarthrum opuntia** (J. Ag.) Boergs. nov. comb.—*Chondria opuntia* J. Ag., in Linnæa, 1841, vol. 15, p. 21. *Lomentaria* (?) *opuntia* J. Ag., Spec. Alg. vol. II, p. 737. KYLIN, Die Florideengattung Rhodymeniales (Lunds Universitets Aarsskr. N. F. Avd. 2, vol. 27, 1931, p. 33, tab. 20, fig. 48). *Gastroclonium opuntia* (J. Ag.) Kütz., Spec. alg., p. 866. *Chrysymenia opuntia* Endl., Gen. Pl., Supplem. III, p. 42. WEBER VAN BOSSE, Alg. Siboga, p. 468.

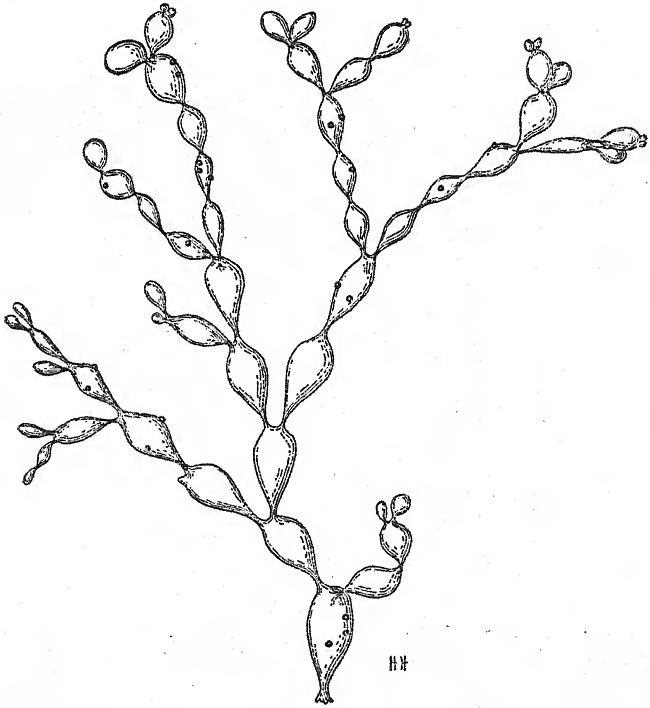

Fig. 9.—*Coelarthrum opuntia* (J. Ag.) Boergs. Habit of a cystocarpic specimen. Natural size.

As will be seen from the quotation given above, this plant has been referred to several genera. J. AGARDH at first considered it to be a *Chondria*, then a *Lomentaria* though with a query. KÜTZING refers it to his genus *Gastroclonium* and Mme. WEBER joins ENDLICHER in placing it in the genus *Chrysymenia*. Mme. WEBER gives a description of the plant accompanied by a transverse section of a cystocarp and writes that it cannot be a *Lomentaria* but a *Chrysymenia*. She points out though that in several respects the plant reminds one of the genus *Coelarthrum*. Finally KYLIN has examined the original specimen in J. AGARDH's herbarium ; he points out that by means of this specimen he was unable to decide its systematic position and adds: " Unmöglich ist aber nicht, dass sie sich am nächsten den Gattungen *Erythrocolon* und *Coelarthrum* anschliesst." KYLIN found that the wall of the vesicles is composed of 2-3 layers of large cells covered by a cortical layer of small cells. Rhizoids are not present and gland cells were not observed.

From an examination of a fine female, but dried, specimen in IYENGAR's collection, it seems evident to me that this plant belongs to the genus *Coelarthrum*. In material soaked in water, it was found that on the wall of the large cells facing the cavity of the inflated joints of the thallus, gland cells occur placed on irregularly shaped or stellate cells (Fig. 10 b) quite in conformity with those found in the type species of this genus, *Coelarthrum Albertisii* (compare my figures 390 and 391 in Mar. Alg. D. W. I. vol. II, p. 404-6). A transverse section (Fig. 10 a) of the wall shows it to be composed of about two layers of large cells, the larger ones innermost and covered by a dense layer of cortical cells. The arrangement of the cystocarps is quite similar to that of *C. Albertisii* (compare my figure 389 B.)

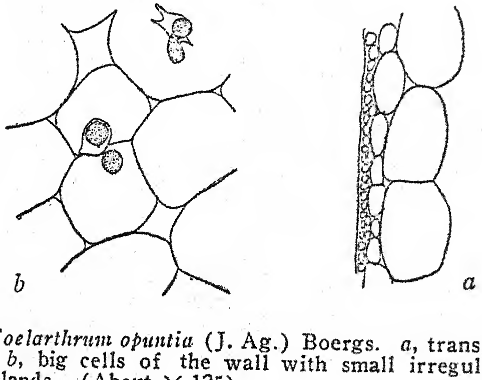

Fig. 10.—*Coelarthrum opuntia* (J. Ag.) Boergs. *a*, transverse section of the thallus; *b*, big cells of the wall with small irregularly stellate cells carrying glands. (About × 125).

Coelarthrum opuntia is surely closely related to *Coelarthrum Muelleri* (Sond.) Boergs. (in Kew Bull. 1931, no 1, p. 9, fig. 6-7), but nevertheless easily distinguishable from this plant by its smaller thallus, its shorter and proportionately broader segments and in its more delicate structure in all respects. Thus a transverse section of the thallus shows that the wall of *C. opuntia* is composed of 1-2 layers of large cells generally covered by a single layer of cortical cells, whereas *C. Muelleri* has 2-3 layers of large cells and a cortical layer of two or more layers. Finally the innermost large cells in *Coelarthrum Muelleri* are almost twice as big (about 375μ long) as those in *Coelarthrum opuntia* (about 200μ long). If well preserved material (in alcohol) of *C. opuntia* were available it might perhaps be possible to find out other differences also for distinguishing the two plants.

India: Tuticorin, 16 Oct. 1900 a female plant leg. K. RANGACHARY; Danushkodi, Oct. 1922, a sterile specimen, "washed ashore" leg. M. O. P. I.

Distr.: India, Malayan Archipelago.

Botryocladia (J. Ag.) Kylin.

1. **Botryocladia leptopoda** (J. Ag.) Kylin.

Forma LUXURIANS Boergs. Some Mar. Alg. Arabian Sea, p. 39, where literature is quoted.

In IYENGAR's collection some fine specimens of this stately plant are present. They agree very well with those found by me at Dwarka. The specimens are about 30 cm. high. The vesicles are pyriform-globose in shape and vary very much in size; they are about 2-4 mm. broad. The wall of the vesicles is about 65μ thick and consists of one layer of large cells covered by a cortical layer one to two cells thick.

India: Cape Comorin, Sept. 1924, leg. M. O. P. I.

Distr.: Arabian Sea, Malayan Archipelago, Japan, Australia.

VI Ceramiales.

Fam. 1. ***Ceramiaceæ.***

Sub-fam. 1. ***Spermothamnieæ.***

Spermothamnion Areschough.

1. **Spermothamnion** spec.

A sterile *Spermothamnion* forming tufts 2-3 cm. high is found in IYENGAR's collection. Its creeping basal filaments are fixed to the substratum with unicellular rhizoids ending in a broad disc with coralliform outline. The cells in the basal filaments are 80 μ broad and about 150 μ long. The erect filaments are about 70 μ broad and the cells have a length of about 190 μ. Upwards the filaments are irregularly ramified.

India: Cape Comorin, Oct. 1924, leg. M. O. P. I.

Sub-fam. 2. ***Monosporeæ.***

Pleonosporium Naegl.

1. **Pleonosporium Borreri** (Engl. Bot.) Naegl., Beitr. zur Morphologie u. System. der Ceramiaceæ, 1861, p. 342. Hauck, Meeresalgen p. 87.—*Conferva Borrri* Engl. Bot., tab. 1741. For more synonyms compare De-Toni, Syll. Alg. p. 1303.

The Indian plant of which I have had only very little material seems to agree very well with this species, but nevertheless I think that a short description of the Indian plant accompanied by a few figures might be of some use.

The plant forms small dense tufts (on stones ?) upto about 2 cm. high. The base (Fig. 11a) consists of the lower decumbent parts of the filaments and is fixed by means of rhizoids to the substratum. Such rhizoids are also now and then developed higher up in the filaments (Fig. 11c) and when they come into contact with a suitable substratum may be able to produce new plants.

In the lower decumbent part, the filaments are moniliform and are not very thick, but become thicker and cylindrical upwards. The main filaments have a breadth of about 140-200 μ with thick walls. In the basal part, the cells are about as long as broad, but higher up in the filaments they are about 2-3 times as long as broad.

In the lower parts of the filaments the branches are placed in a spiral manner (Fig. 11 b.) and are given out on all sides. Higher up they are more or less alternately placed in two rows one on either side of the main filaments (Fig. 11 c.) Some of the branches are ramified from near the base, some are more or less unbranched or form at their upper ends a few short oppositely placed ramuli (Fig. 11 d.) As a rule the branchlets are somewhat incurved, especially in the upper part of the thallus, enclosing the young parts of the thallus with their upper ends.

The only kind of fructiferous organs found are polysporous sporangia (Fig. 11 e) which contain a very large number of spores (about 12-20). The sporangia are placed in rows on the upper ventral side of the filaments near their base. They are oval-obovate in shape, about 60 μ broad and 75 μ long. Their wall is about 5 μ thick.

India: Pamban, April 1924, leg. M. O. P. I.

Distr.: Warm Atlantic coast of Europe, Mediterranean Sea, China.

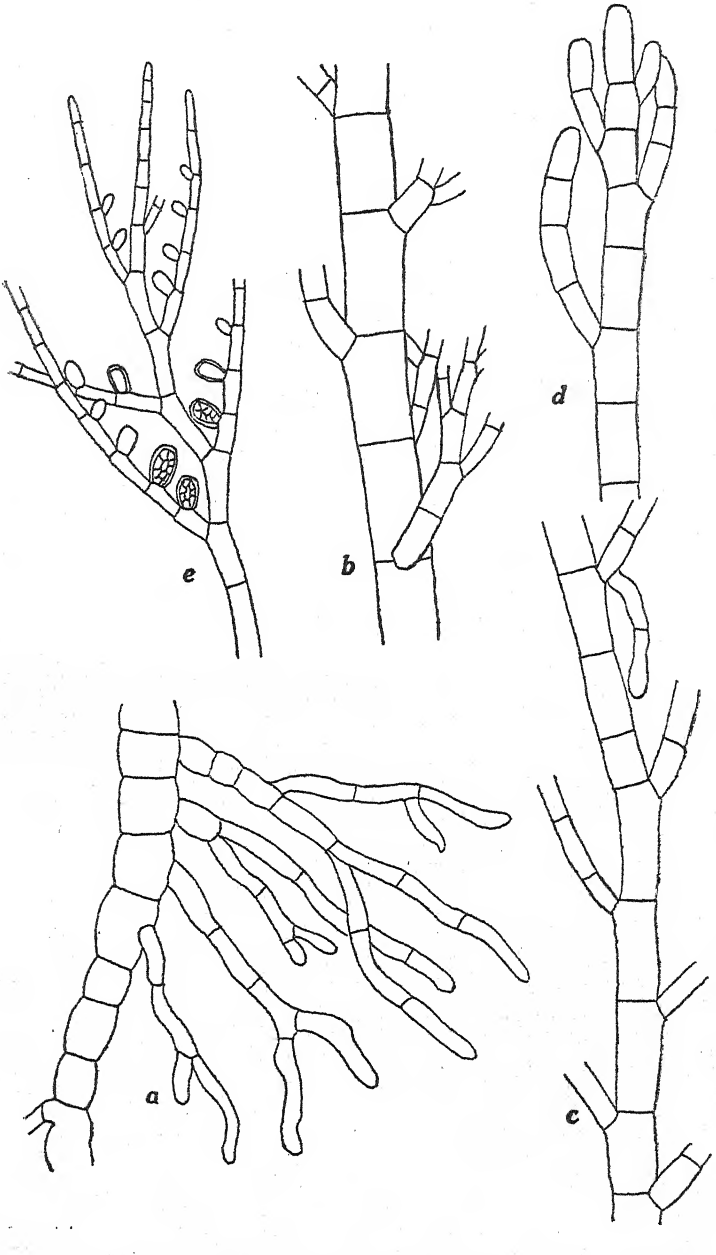

Fig. 11.—*Pleonosporium Borreri* (Engl. Bot.) Naegl. *a*, base of a filament; *b*, lower part of a filament; *c*, part of a filament higher up; *d*, upper end of a filament; *e*, ramified part of the thallus with polyspores. *a*, *c*, *e*. × 80 ; *b*, *d*. × 125.

Sub-fam. 3. ***Wrangelieæ.***

Wrangelia C. Ag.

1. Wrangelia Argus Mont., Sylloge generum specierumque Cryptogamarum, Paris 1850, p. 444. BOERGESEN, Mar. Alg. D. W. I., vol. II, p. 116. OKAMURA, Icones Japan. Algae, vol. V, 1934, p. 46, pl. 324.—*Griffithsia Argus* Mont. in WEBB et BERTHELOT, Hist. nat. des iles Canaries, vol. III, sect. III, Paris 1830-50, p. 176, tab. 8, fig. 4. *Wrangelia plebeja* J. Ag., Spec. Alg., II, 3, 1863, p. 707; Epicrisis, 1876, p. 623.

Several gatherings containing tetrasporic and male specimens are found in IYENGAR'S collection. In my West Indian and Canarian material the rhizoidal layer surrounding the large cells in the filaments was not much developed. But in the Indian specimens the decumbent rhizoids originating from the basal cells of the short shoots in the older parts of the thallus formed a thick but rather loose covering round the large cells. OKAMURA (l. c.) gives a good figure of the development of this rhizoidal covering, and his figure 6 shows a transverse section of a cell with a thick covering of rhizoids. Like the Japanese plant (compare OKAMURA'S fig. 1) the Indian plant was rather large, a good deal larger than those found by me.

India: Krusadi Island, Pamban, Oct. 1924 and Sept. 1928, leg. M. O. P. I.

Distr.: West Indies, Canary Islands, Malayan Archipelago, Japan.

Sub-fam. 4. ***Spyridieæ.***

Spyridia Harv.

1. Spyridia fusiformis nov. sp. Thallus cæspitosus, corticatus, teres, articulatus, in media parte thalli submoniliformis, ca. 6-7 cm. altus et 1 mm. latus, ad apicem versus gradatim attenuatus, irregulariter ramosus. Rami sparsi, quoquoversum vage egredientes, fusiformes, breves aut plus minus elongati. Articuli ramorum diametro duplo vel triplo breviores. Ramelli sparsi nullo ordine egredientes, articulati, ad genicula leviter corticati, tenuissimi, piliformes et mox decidui, ca 1 mm. longi et ca 25μ lati, ex articulis diametro ca 2-3 plo longioribus, apice frustuloso, 2-3 cellulis parvis subconicis instructo compositi.

India: Krusadi Island, Pamban, Oct. 1924, leg. M.O.P.I.

The few tufts found in the collection reached a height of about 6-7 cm. The base consists of a flat disc from which a number of erect shoots arise. The thallus is terete and articulate, the main stems becoming moniliform in their lower part. The main filaments have a diameter of about 1 mm. or a little more and the distance between the articulations in the lower parts

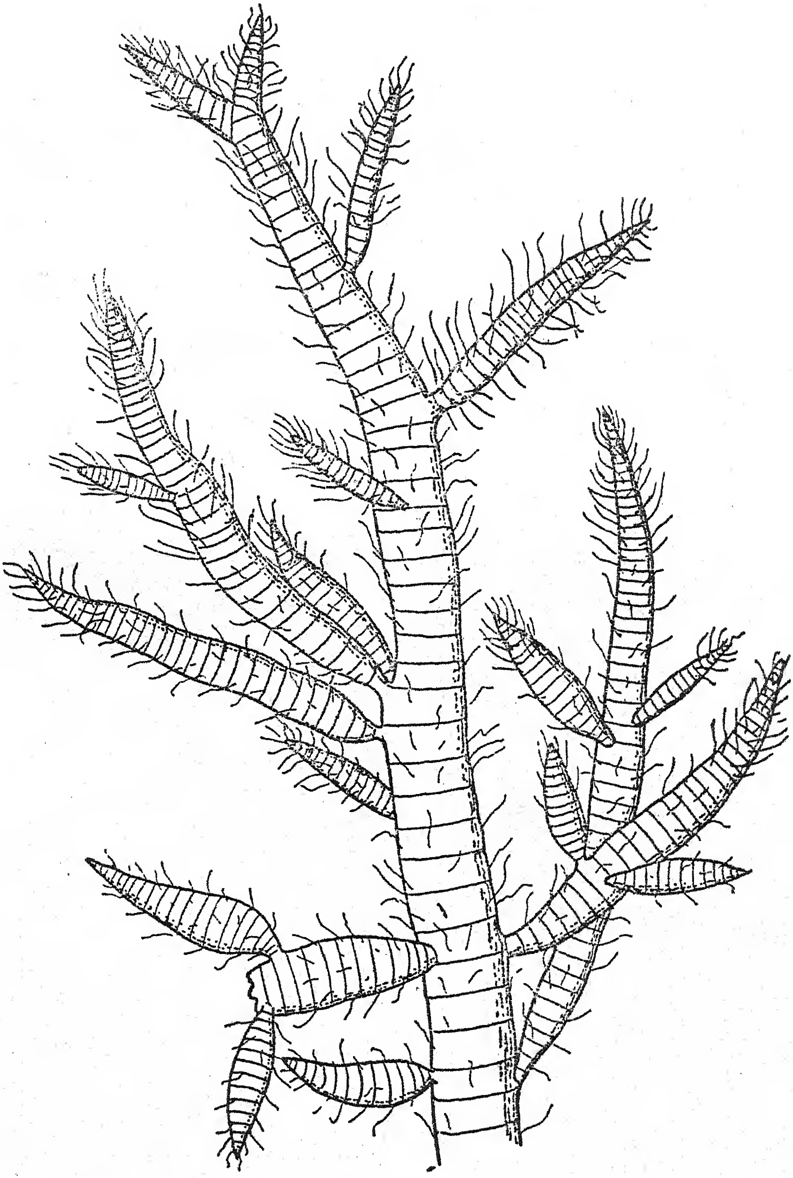

Fig. 12.—*Spyridia fusiformis* Boergs. Part of the thallus. × 8.

is about half the breadth of the filament, but in the upper parts and in the ramuli it is about 1/3-1/4 only. The cortical layer (Fig. 14) consists of elongated cells placed irregularly in the direction of the stem. The lower parts of the main filaments are not or only rarely branched, but they get much branched upwards. The ramification is quite irregular, branches and branchlets being given off on all sides. A few of the branches grow out like main filaments and are not or only very little constricted at their bases, but generally most of the lateral branches have only a limited growth. These are fusiform in shape, short or long, and very much constricted near the base and tapering from the middle towards the acute apex (Fig. 12).

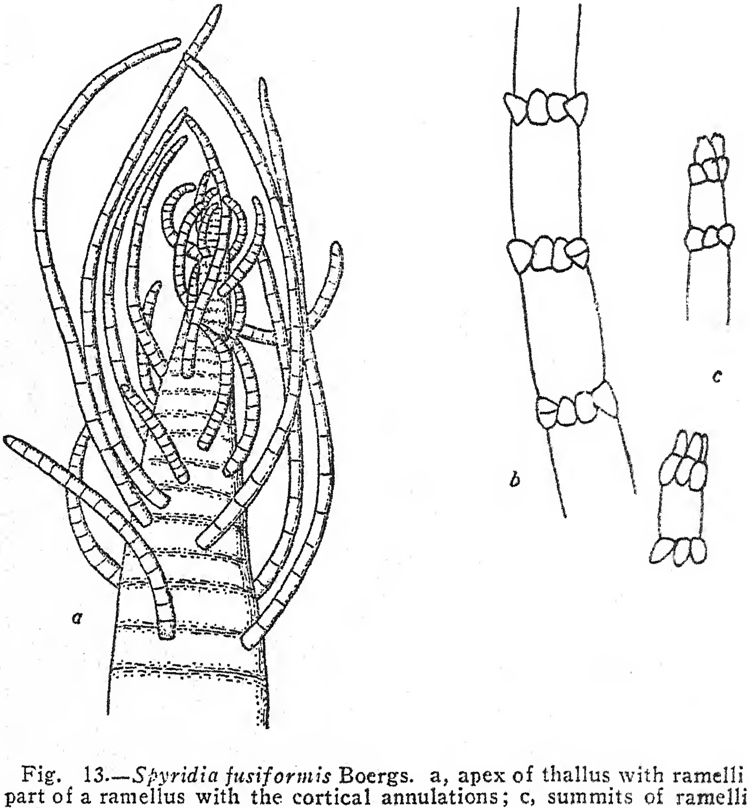

Fig. 13.—*Spyridia fusiformis* Boergs. a, apex of thallus with ramelli; b, part of a ramellus with the cortical annulations; c, summits of ramelli. a, about × 85, b,c about × 250.

The ramelli (Fig. 13) are given out on all sides and are placed very irregularly, young ones growing out between the older ones. They are very thin and ephemeral, dying away early so that the older parts of the thallus become bare. They are often rather long (more than 1 mm. long), but only 25μ thick; the cells are about 250μ long. The cortical annulation at the crosswalls is generally composed of only a single row of cells, now and then some of the cells become divided into two cells (Fig. 13, b). In the upper ends a few, 2-3, rather large thick-walled cells are found provided at their upper ends with some quite small protuberances (Fig. 13, c), but no hooks are present.

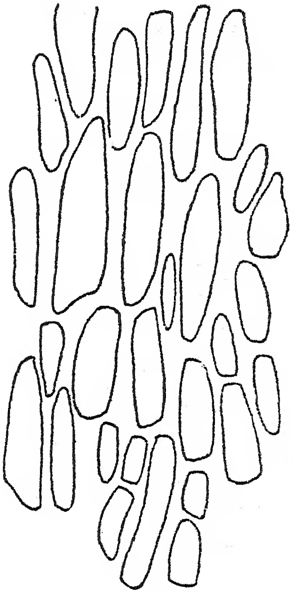

Fig. 14.—*Spyridia fusiformis* Boergs. Part of the cortical layer. × 400.

On account of its thin feeble ramelli, this species shows some likeness to some forms of *Spyridia filamentosa* and related species, but it differs especially in the markedly fusiform shape of the branches, in the irregular arrangement of the cortical layer and in the ramelli having no spines.

2. Spyridia insignis J. Ag., Spec. II, p. 344; Epicrisis, p. 272.—*Spyridia ericoides* Kütz. in Bot. Zeit. 1847; p. 37. Spec., p. 668; Tab. Phycol., vol. XII, tab. 52 a-b. *Spyridia tetracantha* Kütz., Tab. Phyc., vol. XII, tab. 52 d, e. *Bindera insignis* J. Ag., Adversaria, p. 36.

A few specimens are to be found in the collections examined by me.

India: Cape Comorin, Sept. 1920 and 1924, M. O. P. I. Trivandrum, Travancore, Jan. 1934, leg. E. K. JANAKI and E. W. ERLANSON.

Distr.: India, Cape, Dar es Salaam.

Fam. 2. *Delesseriaceæ.*

Sub-fam. 1. Delesserieæ.

Caloglossa Harv.

1. **Caloglossa Leprieurii** (Mont.) J. Ag., Epicrisis, p. 499. ERIKA POST, Systematische und pflanzengeographische Notizen zur *Bostrychia-Caloglossa*-Association (Revue algologique, vol. 9, p. 51).—*Delesseria Leprieurii* Mont., in Ann. Sc. Nat., Bot., sér. 2, vol. 23, p. 196, tab. V. fig. 1.

A narrow form among which a few filaments of a sterile *Spirogyra* was present in IYENGAR'S collection. The thallus reached a breadth of up to about 800μ, which is a little broader than the measure given by MISS POST for her forma *pygmaea*. A few tetrasporic bits of the thallus were found, but most of the material was sterile and apparently in active vegetative division.

India: Quilon in Travancore in the brackish backwater, growing attached to small stones, Oct. 1924, leg. M.O.P.I.

Distr.: Widely distributed in warm seas.

Sub-fam. 2. Nitophylleæ.

Nitophyllum Grev.

1. **Nitophyllum marginale** Harv. in KÜTZING, Tab. Phyc., XIX, p. 2. HARVEY, Ceylon Alg. No. 26. KYLIN, Studien über Delesseriaceen, p. 76.—*Aglaophyllum marginale* Kütz., l. c., pl. 5.

A single young sterile specimen is found in IYENGAR'S collection. It is quite like the specimens gathered by me at Galle.

India: Tuticorin, March 3rd 1928, leg. M.O.P.I.

Distr.: Ceylon.

Acrosorium Zanard.

Acrosorium uncinatum (J. Ag.) Kylin, Studien über die Delesseriaceen p. 78, fig. 61.—*Nitophyllum uncinatum* J. Ag., Spec. Alg., II, p. 654. *Cryptopleura lacerata* var. *uncinata* Kütz., Tab. Phyc., vol. 16, tab. 25 e. *Fucus laceratus* var. *uncinatus* Turn., Hist. Fucorum, tab. 68, figs. c-d.

Some sterile specimens preserved in formalin are found in IYENGAR's collection.

India: Cape Comorin, Oct. 1924, leg. M.O.P.I.

Distr.: Warm Atlantic European Coast, Canary Islands, Mediterranean Sea, Cape, Malayan Archipelago, Japan.

Sub-fam. 3. ***Sarconemieæ.***

Claudea Lamour.

1. Claudea multifida Harv. in Hooker Journ. of Bot., vol. VI, p. 145; Ceylon Algæ No. 2. KÜTZING, Tab. Phyc., vol. 19, pl. 56.

India: Tuticorin, March 3rd 1928, leg. M.O.P.I.

Distr.: Ceylon, South-India.

Vanvoorstia Harvey.

1. Vanvoorstia spectabilis Harv. in HOOKER, Journ. of Bot.. vol. VI, p. 144; Ceylon Alg. Exsicc. no 3. KÜTZING, Tab. Phycol., vol. 19, tab. 56. WEBER VAN BOSSE, A., Algues Siboga, p. 390, fig. 141.

A few small sterile specimens are found in IYENGAR's collection.

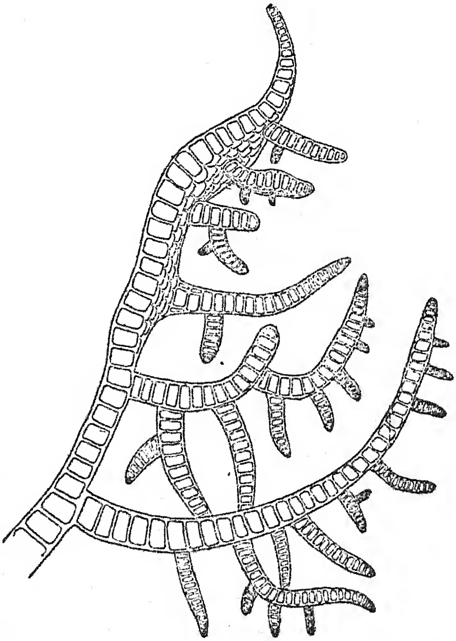

Fig. 15.—*Vanvoorstia spectabilis* Harv. A small part of the young thallus. compare the text. × 50.

In Fig. 15 a small part of the young thallus is drawn to show how it is built. In contrast to *Claudea* the branchlets forming the net are given out from the underside of the branches of first order whereas in *Claudea* they issue from the upper side of the branches. Furthermore, the meshes of the net are oblique in *Vanvoorstia* (not so clearly seen in the figure), whereas they are rectangular in *Claudea*.

India: Shingly Island, Pamban "on coral stone", May and Oct. 1920, leg. M. O. P. I.

Distr.: Ceylon, Malayan Archipelago, Japan, Hawaii.

Martensia Hering.

1. **Martensia fragilis** Harv. in Hooker, Journ. Bot., vol. 6, p. 145; Ceylon, Alg. exsicc. no. 5.

Some rather small, sterile specimens found in Iyengar's collection certainly belongs to this species. As pointed out by Svedelius in his valuable publication on *Martensia*, the non-reticulate part of the thallus is as a rule much developed before the net begins to grow out, and this was also the case in the two Indian specimens.

India: Shingly Island, Pamban, Oct. 1924, leg. M.O.P.I.

Distr.: Ceylon.

Fam. 3. ***Dasyaceæ.***

Heterosiphonia Mont.

1. **Heterosiphonia stuposa** (J. Ag.) De-Toni, Syll. Alg. p. 1235.—*Dasya stuposa* J. Ag., Sp. Alg., II, 3, p. 1197. Till Algernes Systematik, Nya Bidrag XI, Florideæ, 1890, p. 86.

Like *Heterosiphonia Muelleri* (compare my description in Kew Bulletin, 1931, p. 18) this species has a thick, fleshy-cartilaginous, irregularly ramified, terete base fixed firmly to the substratum. From this base, which is most probably perennial, erect shoots issue, living, as I presume, during the favourable season only. In the few specimens I have seen, the erect shoots reach a length of about 9 cm. They have no cortical layer, and near the base they are about 1 mm. thick with barrel-shaped segments composed of 9-11 pericentral cells round the central cell. Agardh in "Species" says 7-9 pericentral cells, but in "Till Algernes Systematik" corrects it to 11. The free ends of each branch system of the sympodium are a little more than 1 cm. long and issue alternately in two rows on either side of the main filament giving the whole shoot-system a pinnate appearance. They are provided with short pinnules, about ½ mm. long, which are branched a few times and which end in long, repeatedly forked monosiphonous filaments which are about 30 μ thick near the base decreasing to about 10-11 μ thick at the upper ends.

The specimens were sterile.

I compared the Indian plants with some of FERGUSON's specimens from Ceylon at the British Museum (Nat. Hist.), London. The Indian plants agree very well with those from Ceylon.

India: Tuticorin, Pearl Bed, March 1928, M.O.P.I.

Distr.: Ceylon.

Dasya C. Ag.

1. **Dasya Iyengarii** sp. nov.

Frons nana, ca. 3 cm. alta, epiphytica, mollissima, leviter corticata, penicillato-villosa, irregulariter ramosa. Penicilli quoque versum exeuntes, ca 500-600 μ longi, monosiphonii, interdum in parte basali plurisiphonii, sursum leviter attenuati, squarroso-subdichotomi, ramellos valde incurvos, hamosos, apicibus subobtusis gerentes. Stichidia oblonge-lanceolata, apicibus subacutis, ca 500 μ longa et 100 μ lata.

India: Pamban Bridge, May 1924, leg. M.O.P.I.

The plant forms small dense, soft, much ramified tufts on *Gelidiopsis variabilis* (Fig. 16). The tufts are about 3-4 cm. high, and the only dried specimen seen by me has a dark brown to red colour. The thick main stems are about 300 μ thick, tapering upwards to about 150-200 μ. The stems consist of a central and 5 pericentral cells. The cortical layer is feebly developed consisting only of rhizoids running down along the furrow between the pericentral cells (Fig. 17). The penicilli are given out in a scattered manner on all sides. They are generally purely monosiphonous, though now and then in the most vigorously growing portions

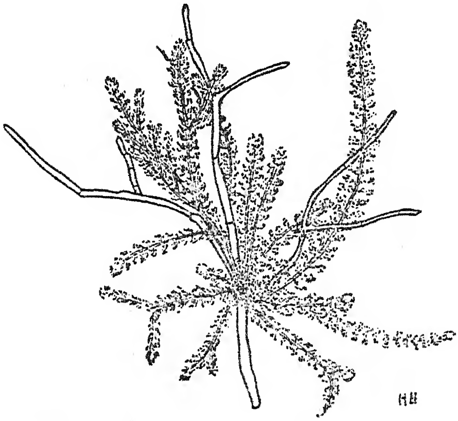

Fig. 16.—*Dasya Iyengarii* Boergs. Habit of a small plant epiphytic on *Gelidiopsis variabilis*. × 3.

a few polysiphonous segments are found at the base. Occasionally a branch becomes developed instead of a penicillus. The penicilli are subdichotomously divided (as to the real building up of the penicillus compare FALKENBERG, Rhodomelaceen, p. 611), reaching a length of 500-600 μ and completely envelop the main stems. The ramuli are much curved and hook-shaped (Fig. 17).

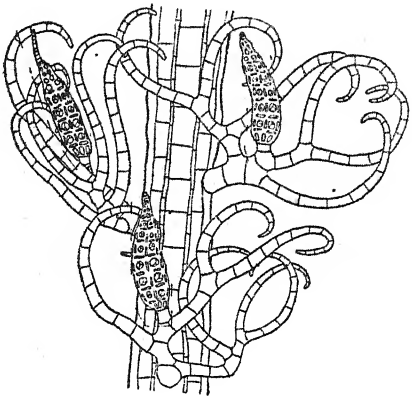

Fig. 17.—*Dasya Iyengarii* Boergs. Part of the thallus with stichidia. × 50.

Near the base, the penicilli are about 80-90 μ thick tapering slowly upwards. The apex is obtuse. The stichidia are oblong-lanceolate, tapering upwards and as a rule provided with a sterile short filament ending monosiphonously (Fig. 17). The dried specimen adheres strongly to paper.

Dictyurus Bory.

1. Dictyurus purpurascens Bory in Belanger, Voyage Ind. orient., tab. I, p. 170 (after DE-TONI). J. AGARDH, Spec. Alg., II, 3. p. 1245. FALKENBERG, Rhodomelaceen, p. 675, tab. 17, figs. 10-24.

The first specimens which were described of this plant were gathered by BELANGER at Cape Comorin. The plant is common at Tuticorin. The specimens examined by me were sterile.

India: Tuticorin, Hare Island, Oct. 1923, M.O.P.I.; March 1929(!).

Distr.: Indian Ocean.

Fam. 4. **Rhodomelaceæ.**

Sub-fam. 1. ***Laurencieæ.***

Laurencia Lamx.

1. Laurencia papillosa (Forssk.) Grev., Alg. Brit., p. 52. J. AGARDH, Spec. Alg. II, p. 756. KÜTZING, Spec. Alg. p. 665 and Tab. Phyc. vol. XV, pl. 62. BOERGESEN, Mar. Alg. D. W. I., p. 246, fig. 236. YAMADA, Notes on *Laurencia*, p. 190.—*Fucus papillosus* Forssk., Fl. Ægypt.-Arab., p. 190.

Several well developed specimens are present in IYENGAR'S collection.

India: Tuticorin, Febr. 1928, leg. M.O.P.I.; Krusadi Island, Pamban, May 1924, leg. M.O.P.I.

Distr.: Warm Atlantic Ocean, Mediterranean and Red Seä, Indian Ocean, etc.

2. Laurencia indica Hauck in Hedwigia, vol. 27, 1888, p. 90. YAMADA, Y., Notes on *Laurencia*, p. 205, fig. I, pl. 6, fig. b.

In IYENGAR'S collection some tetrasporic specimens preserved in formalin seem to agree very well with HAUCK'S description. Lenticular thickenings were found in the medullary tissue. I have not been able to compare the specimens with authentic material.

India: Tuticorin, leg. M.O.P.I.

Distr.: East Africa.

3. Laurencia ceylanica J. Ag., Epicrisis, p. 660.—*Laurencia* spec. HARVEY, Alg. Ceylon, no 17. YAMADA, Notes on *Laurencia*, p. 244, pl. 30, fig. a.

A fine large specimen collected in Sept. 1924 is found in IYENGAR'S collection, another one collected in April of the same year is quite small.

India: Cape Comorin, Sept. 1924, Krusadi Island, April 1924, leg. M. O. P. I.

Distr.: Ceylon, Shikoku (after YAMADA). Hawaian Islands according to a specimen in the Botanical Museum, Copenhagen, and determined by REINBOLD.

Sub-fam. 2. ***Chondrieæ.***

Chondria Ag., Harv.

1. Chondria dasyphylla (Woodw.) Ag., Spec. Alg., p. 350; Systema, p. 205. HARVEY, Nereis Bor.—Am. II, p. 20. FALKENBERG, P., Rhodomelaceen, p. 197, pl. 22, figs. 4-18.—*Fucus dasyphyllus* Woodw., in Transact. Linnean Soc., vol. II, 1794, p. 239, pl. 23, figs. 1-3.

Male and female specimens like my figures 251 and 252 in Mar. Alg. D. W. I., vol. II, p. 258 are found in IYENGAR's collection. The specimens were epiphytes on leaves of a sea-grass.

India: Krusadi Island, April 1924, leg. M.O.P.I.

Distr.: In most warm seas.

2. **Chondria armata** (Kütz.) Okamura, Icones Jap. Alg., vol. I, pl. 16, figs. 9-19. WEBER VAN BOSSE, Alg. Siboga p. 353.—*Lophura armata* Kütz., Tab. Phyc. vol. XVI, tab. 3, figs. a,b. *Rhodomela crassicaulis* Harv., Alg. Ceyl. exsicc. no 8. SVEDELIUS in Botaniska Studier tillägnade F. R. KJELLMAN, p. 191, figs. 3 and 9. *Chondriopsis crassicaulis* J. Ag., Analecta Algologica, 1892, p. 161. *Chondria minima* Weber, Alg. Siboga, p. 309, pl VII, fig. 9.

Var. PLUMARIS Boergs. in Kew Bull. no 3, 1932, p. 132-4.

India: Tuticorin, Hare Island, March 1928, (!) Pearl Bed, Febr. 1928, leg. M.O.P.I. Pamban Bridge, April 1924, leg. M. O. P. I. Trivandrum, Travancore, Jan. 1934, leg. E. K. JANAKI and E. W. ERLANSON.

Distr.: Ceylon, India, Malayan Archipelago, Japan, etc.

Acanthophora Lamx.

1. **Acanthophora muscoides** (L) Bory. Voyage Coquille, p. 51. J. AGARDH, Species, II, 3, p. 816.—*Fucus muscoides* L., Spec. plant. II, p. 1630.—*Chondria muscoides* Ag., Spec., p. 361.

In some material gathered by IYENGAR, tetrasporic specimens were found. The tetrasporangia occurred in almost unaltered branchlets densely covered by spines, scattered spines being also present on the branches. Because of these characters the specimens must be referred to *Acanthophora muscoides*. As I have pointed out in earlier papers on algæ from India, my material was in most cases sterile, and therefore my referring of the specimens to *Acanthophora Delilei* is perhaps not correct.

India: Tuticorin, Oct. 1923, leg. M.O.P.I.

Distr.: West Africa, Cape, Japan, Fidschi-Islands, Brazil, West Indies, etc.

2. **Acanthophora spicifera** (Vahl.) Boergs., Mar. Alg. D. W. I., vol. II, p. 259, figs. 253-8. WEBER, A., Algues Siboga, p. 347.—*Fucus spiciferus* Vahl, Endeel kryptogamiske Planter fra St. Croix (Skrivter af Natur historie-Selskabet, 5. Bd., Koebenhavn 1802. *Acanthophora Thierii* Lamx., Essai....... Thalassiophytes, Paris 1813, p. 44. J. AGARDH, Spec. Alg., vol. II, 3, p. 819.

Some specimens found in IYENGAR's collection are referable to this species.

India: Cape Comorin, Oct. 1924, leg. M.O.P.I.

Distr.: West Indies, Malayan Archipelago, Ceylon.

Sub-fam. 3. ***Polysiphonieæ.***

Polysiphonia Grev.

Polysiphonia platycarpa Boergs. in Kew Bulletin, 1934, p. 33, figs. 15-17; List Mar. Alg. Bombay, p. 60.

Several dried specimens are found in IYENGAR's collection; the cystocarps in a female plant were about 400μ long and broad.

In the last paper quoted above, I have pointed out that this species is closely related to or perhaps the same as *Polysiphonia mollis* Hook. et Harv.

India: Madras, Adyar estuary near Bridge, in brackish water, leg. M.O.P.I.

Distr.: India.

Bryocladia Schmitz.

1. **Bryocladia Thwaitesii** (Harv.) De-Toni, Syll. IV, 968.— *Polysiphonia Thwaitesii* Harv., Ceylon Alg. no 15. MURRAY, Catalogue, p. 31. KÜTZING, Tab. Phycol. XIV, tab. 46, fig. d-g.

The plant grows in dense tufts about 4-5 cm high. The base consists of decumbent creeping filaments felted together. These filaments are fixed to the substratum by means of vigorous unicellular rhizoids ending in a flat disc with irregular outlines. The decumbent creeping filaments are ramified and after some time bend upwards giving rise to erect shoots.

The basal filaments as well as the erect ones are quite without any cortical layer. The plant has a varying number of pericentral cells, up to about 11 in the vigorous filaments. The erect filaments have monopodial growth. In the lower part they are quite unbranched or nearly so with several bare segments between those that carry branches, higher up they become densely ramified, branches being given out from almost every segment. The branches are placed in a spiral to the left.

The branches are ramified several times in the same way. There are no or only a few branches in the lower parts, higher up they are placed more densely. The side branches are often unbranched and spine-like or provided with a few spine-like branchlets at their upper ends. The branchlets curve more or less towards the main axis.

Only specimens with tetrasporangia are found. The tetrasporangia are found in the upper spine-like branchlets, one in each segment and in a straight line.

India: Madras, Rayapuram Beach, Aug. 1926, leg. M.O.P.I.

Distr.: Ceylon.

Roschera Sond.

1. **Roschera glomerulata** (Ag.) Web. v. Bosse, Rhodophyceæ Percy Sladen Trust Exp. (1914) p. 289; Liste Alg. Siboga, p. 359. OKAMURA, Icones Jap. Alg. vol. IV, (1922), p. 155, tab. 188. BOERGESEN in Kew Bulletin 1931, p. 17, fig. 11.—*Hutchinsia glomerulata* C. Ag., Spec. Alg. II, p. 102. *Tolypocladia glomerulata* Schmitz in Engl. Bot. Jahrb. vol. 21, p. 160. *Falkenberg,* Rhodomelaceen, p. 177 tab. 21, figs. 27-29.

Fine tetrasporic specimens were found. As described by FALKENBERG, one or two tetrasporangia are formed in the branchlets.

India: Krusadi Island, April 1926, leg. M.O.P.I.

Distr.: Indian and Pacific Oceans.

Sub-fam. 4. ***Lophothalieæ.***

Lophocladia Schmitz.

1. **Lophocladia Lallemandi** (Mont.) Schmitz, Die Gattung *Lophothalia* J. Ag. in Ber. d. deutsch. bot. Ges., XI, p. 223. FALKENBERG, Rhodomelaceen, p. 552. BOERGESEN, in Kew Bull. 1934, p. 28, fig. 19.—*Dasya Lallemandi* Mont., in Ann. Sci. Nat., Bot., 12, p. 289 (1849).

A badly preserved, sterile specimen was found in IYENGAR's collection.

India: Tuticorin, Pearl Bed, March 3rd 1928, leg. M.O.P.I.

Distr.: Mediterranean Sea, Red Sea, Indian Ocean.

Murrayella Schmitz.

1. **Murrayella periclados** (Ag.) Schmitz, Die Gattung *Lophothalia.* (Berichte d. deutsch. bot. Ges. XI, 1893, p. 227). FALKENBERG, Rhodomelaceen p. 563, pl. 12, figs. 24-25. BOERGESEN, Mar. Alg. D. W. I., vol. II, p. 314-6, figs. 318-20, where more literature.—*Hutchinsia periclados* Ag., Spec. Alg., vol. II, p. 101.

It was found together with *Caloglossa Leprieurii* and *Bostrychia tenella,* but as to locality there was no information. I have seen only sterile specimens.

India: Cannanore, leg. Miss F. SWAMIKANNU.

Distr.: Much distributed in warm seas.

Sub-fam. 5. **Bostrychieæ.**

Bostrychia Montagne.

1. **Bostrychia tenella** (Vahl) J. Ag., Spec. Alg., vol. II, p. 869. Analecta Algologica, cont. IV, 1897, p. 83. FALKENBERG, P., Rhodomelaceen, p. 515. BOERGESEN, Mar. Alg. D. W. I., vol. II, p. 300-2, figs. 299-302.—*Fucus tenellus* Vahl, Endeel kryptogamiske Planter fra St. Croix (Skrivter af Naturh. Selskab, 5te Bd., Kobenhavn 1802, p. 45).

Fine tetrasporic material is present in IYENGAR's collection In the vegetative parts of the thallus the filaments were altogether monosiphonous or nearly so, whereas in the fruiting parts they were shorter and polysiphonous in the lower half portion or even higher.

As regards the question of separating *Bostrychia Binderi* from *Bostrychia tenella* as a species of its own which has been done by MISS POST in her interesting paper, on the "*Bostrychia-Caloglossa*-Association",* I wish at first to point out that *Bostrychia Binderi* Harv. (Nereis Australis, p. 68, tab. 28, London 1847) must be said to differ very much from *Bostrychia Binderi* Post. In his description, HARVEY says "all the ultimate pinnules short and spinelike", and HARVEY's Fig. 3 shows nothing but short polysiphonous branchlets whereas MISS POST says that above the polysiphonous part *Bostr. Binderi* has a monosiphonous part with 5-15 cells and that specimens with more than 15 cells are to be referred to *Bostr. tenella*. In my opinion this is quite an artificial limitation, and, as it is evident from MISS POST's description also that the true *Bostrychia Binderi* Harvey is connected with transitional forms to *Bostrychia tenella*, I do not think it is right to separate it from VAHL's species, though I think that it may be considered a variety of it. Agreeing with my observations in the West Indies as well as with the well known fact that many algæ are very much influenced by the surroundings, becoming long, thin and flabby in calm and polluted water, but robust and firm in exposed places with clean water, *Bostr. tenella* in the lagoons with stagnant and polluted water possesses long and monosiphonous branchlets, whereas in exposed places its branchlets become short. Of the different localities where I have collected this plant at the Virgin Islands, Great Northside Bay (Store Nordside Bugt), St. Thomas, is just such an exposed locality, and the plant reacts quite naturally to the external conditions found there and gets thicker, shorter and more robust branchlets. Because of this, MISS POST in agreement with her definition of the species refers the specimens I have collected there to *Bostrychia Binderi*. I have not come across in the West Indies any specimens resembling HARVEY's true plant (without monosiphonous prolongations on the branchlets).

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* In Revue Algologique, vol. 9, 1936.

As mentioned by MISS POST (l. c., p. 25), GRUNOW, FALKENBERG and Mme. WEBER have treated this plant in quite the same way as myself. But PILGER also (Die Meeresalgen von Kamerun in ENGLER's Bot. Jahrb. 46, Bd. 1911, p. 306) gives a very detailed description of his specimens showing that his material to a great extent agrees with forms which are referred by MISS POST to *Bostrychia Binderi* but are considered by PILGER to be *Bostrychia tenella.* PILGER writes : "Die Art ist (wohl auch nach den Standortsbedingungen) recht variabel ".

India : Cannanore, leg. Miss J. Swamikannu.

Distr. : Much distributed in warm seas.

Sub-fam. 6. ***Herposiphonieæ.***

Herposiphonia Naegl.

1. **Herposiphonia insidiosa** (Grev.) Falkenberg, Rhodomelaceen, p. 317. OKAMURA, Icon. Jap. Alg. VI, p. 25, pl. 264, figs, 10-16. TSENG, Notes on mar. Alg. from Amoy, 1936, p. 60.—*Polysiphonia insidiosa* Grev. in J. Agardh, Spec. Alg., II, 3, p. 926.

As the species of *Herposiphonia* are often difficult to determine because of the incompleteness of the descriptions, these being generally based on sterile material, I wish to give a short description of a plant which I presume to be *Herposiphonia insidiosa.*

The plant forms a low dense felted cover on large algæ for instance *Gracilaria, Laurencia,* etc. As mentioned by OKAMURA and later by TSENG, the arrangement of the short and long shoots are not always so regular as for instance in *H. tenella* or *secunda* when typically developed. The long shoots are given out irregulary and often at rather variable distances, and the short shoots are placed more or less alternately in two rows often with several bare segments in between.

The decumbent main filaments are much ramified and fixed to the host plants by means of hapters which are often very vigorously developed and the unicellular stems of which may reach a breadth of up to 50-60 μ. The hapters often end in a flat disc with a coralliform, irregular outline, but it may also be unbranched or divided at the end into 2-3 branchlets. The decumbent main filaments are about 200 μ broad and composed of segments somewhat shorter than broad. The short shoots are much curved in the direction of the apex of the plant, they are about 80 μ broad and composed of varying numbers of segments, in the larger ones up to about 30, the length of the segments being about the same as the breadth or a little less. The apex is obtuse. The number of pericentral cells varies very much. I have counted 8-12.

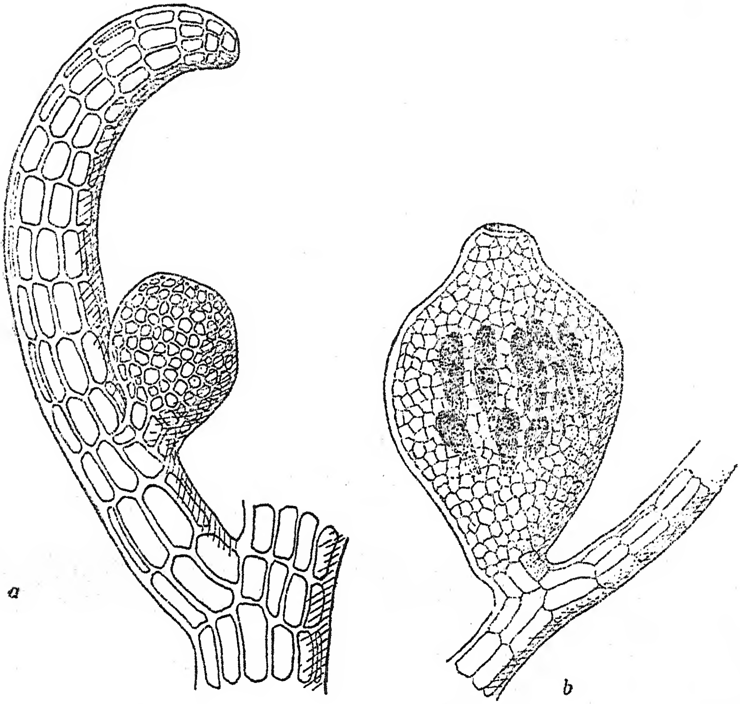

Fig. 18.—*Herposiphonia insidiosa* (Grev.) Falkenb. *a*, a short-shoot with young cystocarp. (× 250). b, a cystocarp. (× 75).

Okamura gives (l. c.) some figures of tetrasporic plants, but cystocarpic specimens do not appear to have been found so far. In a collection of Iyengar's gathered in Oct. 1924 at Cape Comorin, female plants were found and the possibility was now present to decide whether the arrangement of the trichoblasts on the short shoots was spiral (as in *H. tenella*) or dorsiventral (as in *H. rostrata*); compare Falkenberg 1. c. p. 317. But because the trichoblasts are so rarely developed in this species, they seem almost only to be developed for the purpose of propagation, it was only after searching for a long time that I succeeded in finding a short young shoot containing a few very small trichoblasts. The fact that these are given off on different sides shows that the plant belongs to those with spiral arrangements.

As mentioned above, the trichoblasts are very small and often composed of an unbranched filament only; sometimes they may be provided with a few short branchlets. Very few of the short shoots carry cystocarps and, so far as I have seen, each of these shoots have only a single one, very rarely two.

The cystocarps are developed near the base of the short shoots as a rule on the 3-4 segments from the base (Fig. 18a). Antheridial plants were not found.

The ripe cystocarps are large, about 500μ long and 370μ broad; they are elongated-urceolate and get narrow upwards and downwards (Fig. 18b).

India: Cape Comorin, Oct. 1924, and Pamban, April 1924, leg. M.O.P.I.

Distr.: India, Ceylon, China, Japan.

2. Herposiphonia spec.
=*Herposiphonia prorepens* forma Weber ?, Algues Siboga, p. 366.

A small sterile very much ramified *Herposiphonia* forming dense roundish tufts 1 cm. high and of the same breadth on *Amphiroa anceps* seems to agree very well with Mme. WEBER'S description. The ramification of the Indian plant is the *typical* one of *Herposiphonia.* It has 6-11 pericentral cells. The short shoots vary very much in length. Near the periphery of the tufts they are about 270μ long and 20μ broad and composed of about 12-14 segments not so long as broad, whereas nearer the middle of the tufts the short shoots have a length of about 1 mm. and a breadth of about 90μ and are composed of about 20 segments which near the base are twice as long as broad gradually decreasing in length towards the apex, where they are only 1/5 to 1/4 as long as broad. The apex is broadly rounded. A few very small trichoblasts are found in the young short shoots. The decumbent creeping main filaments are about 150μ broad and the segments half the breadth. The short shoots all curve towards the apex. The colour of the plant seems to be lasting. It was found in a tube together with *H. insidiosa* in sea-water containing 6% of formalin and although the last mentioned plant had quite lost its colour this species had kept a dark brownish colour reminding one of that of tufts of *Sphacelaria.*

Mme. WEBER suggests that this may be made a new species, but since the plant is, like Mme. WEBER'S, sterile, I agree with her in preferring to let it remain unnamed.

India: Cape Comorin, Oct. 1924, leg. M.O.P.I.

Sub-Fam. 7. ***Polyzonieæ.***

Leveillea Decsne.

1. Leveillea jungermannioides (Mart. et Her.) Harv. Compare BOERGESEN, Contributions to a South Indian marine algal flora I, p. 389.

On an old piece of *Sargassum* some tetrasporic specimens were found. As pointed out by FALKENBERG, Rhodomelaceen, p. 398, fertile specimens of *Leveillea jungermannioides* are not often found. Generally fructiferous organs are found on small specimens whereas vigorously developed specimens are sterile. FALKENBERG points out that the branchlets in which the sporangia are developed compared with this plant otherwise so slender are almost enormous, and the sporangia too are of large dimensions up to about 200 μ broad. During growth, the fructiferous branchlets become much curved.

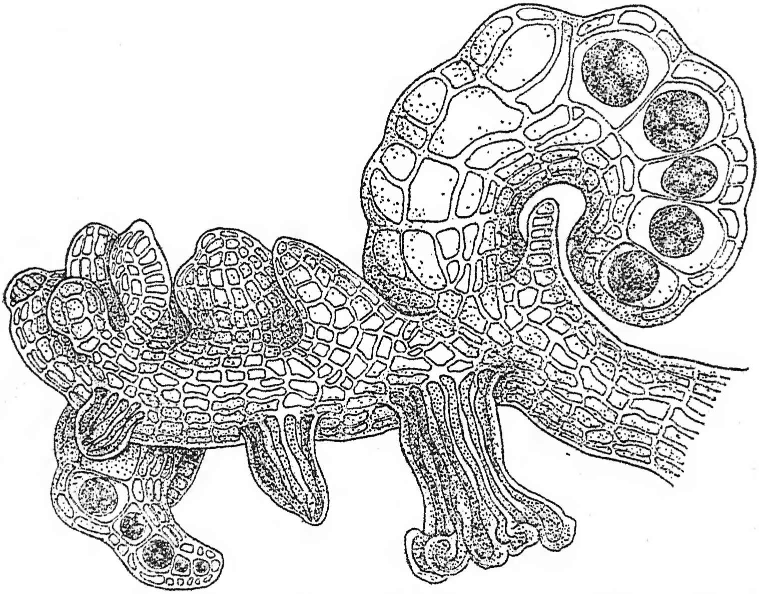

Fig. 19.—*Leveillea jungermannioides* (Mart. et Her.) Harv. A branchlet with stichidia. × 80.

The accompanying figure (Fig. 19) shows a small shoot of this elegant plant with such a much curved stichidium.

India : Shingley Island, June 24, leg. M.O.P.I.

Distr.: Red Sea, Indian Ocean, Australia.

Sub-fam. 8. ***Amansieæ.***

Enantiocladia Falkenberg

1. **Enantiocladia prolifera** (Grev.) Falkenb., Rhodomelaceen, p. 442.—*Amansia prolifera* Grev. in J. AGARDH, Spec. II, 3, p., 1116. *Dictymenia prolifera* Kütz., Spec., p. 848 ; Tab, Phyc. XIX, pl. 54.

Several fertile specimens with tetraspores and cystocarps are found in IYENGAR's collection. Some from Cape Comorin are most probably gathered near the shore and are dark red almost black and firm and robust. A few other specimens from pearl beds near Tuticorin thus gathered in deep sea have a rather thin thallus and are light red. Specimens with tetrasporangia were found in February, female ones in October.

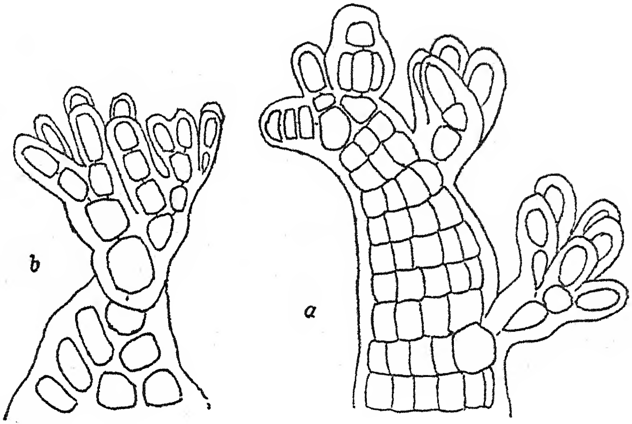

Fig. 20.—*Enantiocladia prolifera* (Grev.) Falkenb. *a*, a branchlet with trichoblasts, the second one from above showing the beginning of the development of the procarp; *b*, branchlet with trichoblast. × 250.

As mentioned by FALKENBERG (Rhodomelaceen, p. 440), *Enantiocladia* differs from *Vidalia* in the oppositely placed shoots issuing from the edges of the flat thallus. A few of these become long shoots, but by far most of them remain short. At the edges of these short shoots, small hooked branchlets (Fig. 20) of the last order are developed and upon these branchlets the trichoblasts are given out. Here and there adventitious branchlets of a similar shape issue from the flat parts of the thallus also. Generally the trichoblasts are developed in rows along the dorsal side of the branchlets, but often also without any order. All the trichoblasts seen by me in the female plants are quite small, being scarcely more than about 100μ high, having short cells with thick walls and being forked only a few times. The branches of the trichoblasts are from the very beginning free and not surrounded by a common cuticle as with the group *Amansieæ* or as with *Neurymenia*, compare my fig.17 in Kew Bulletin 1933, p. 138. Like *Neurymenia* the fertile trichoblasts remain quite short forming only one undivided segment above the fertile one (Fig. 20a). A few, 2-4, rarely more, procarps are developed forming a row along the dorsal side of the branchlets. The trichogyne is thick and proportionally short. After fertilization the cystocarps form a thick, dense cortical layer and become globose with a thick stalk. Generally only one of the procarps seems to be developed on the branchlet. The fully developed cystocarp has a diameter of about 600μ long or more. No ostiole is developed.

In the tetrasporic plant, the small curved branchlets of the third order are transformed into stichidia; furthermore, tetrasporangia are formed on the summits of the branches of the second order. Besides small trichoblasts like those found in the female plant, I found in the tetrasporic plant large well developed, and repeatedly forked trichoblasts having long cells with thin walls. Antheridial specimens were not present.

In Icones of Japanese Algæ, vol. I, pl. X, OKAMURA has given a series of figures of the fructiferous organs of *Enantiocladia latiuscula* (Harv.) Okam. with which those found in *Enantiocladia prolifera* (Grev.) Falkb. are to be compared.

India: Cape Comorin, Sept. 1924, and Tuticorin, Pearl Bed, 3rd Aug. 1928, leg. M. O. P. I.

Distr.: India.

Neurymenia J. Ag.

1. Neurymenia fraxinifolia (Mert.) J. Ag., Spec. Alg. II, p. 1135. Compare Boergesen, in Kew Bull., 1933, no. 3, pp. 137-142, figs. 17-20, where literature is quoted.

In the paper mentioned above, I have given some information about the development of the stichidia, cystocarps and antheridial bodies based upon material gathered at Tuticorin. There I have also pointed out that the varying shapes of the stichidia in plants from different localities might perhaps render it possible to divide this until now monotypic genus. I regret having omitted to mention that J. AGARDH (l. c.) has tried to make such a division especially because of the shape and size of the thallus.

India: Tuticorin, Hare Island, Febr. 1928, leg. M.O.P.I. and (!). Cape Comorin, Sept. 1924, and Krusadi Island, April 1924, leg. M.O.P.I.

Distr.: Indian Ocean, Japan, Australia, etc.

ON THE CULTURE BEHAVIOUR OF A SPECIES OF *ROSELLINIA*

I. Inhibitory Effect of Certain Chemicals on the Production of Perithecia

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Introduction

A species of *Rosellinia* produced numerous perithecia when it was grown in simple agar but no perithecia developed when the fungus was grown in a synthetic medium which, in addition to agar, consisted of asparagin, glucose, magnesium sulphate, potassium phosphate and potato starch in a given proportion. Further there was luxuriant growth of perithecia in the same synthetic medium when *Rosellinia* was grown in association with a bacterium that came as a natural contamination when the fungus was first isolated. Apparently the formation of perithecia is causally related to the nature of the medium employed for growing the fungus. That is to say, there must be present in the synthetic medium some chemical or chemicals which either singly or in combination exert an inhibitory influence on the formation of perithecia. This influence may depend on the very nature of the substance or on the altered acidity, etc., due to the presence of the constituting chemicals. Formation of perithecia in the presence of bacteria also pointed towards the same conclusion.

The present work was undertaken to find out the chemicals responsible for the inhibition of perithecia formation in this species of *Rosellinia*. Various chemicals constituting the standard medium have been tested singly and in combinations for their possible inhibitory effect. This paper which embodies the result of the investigation was read in the twenty-third meeting of the Indian Science Congress, Indore (Das Gupta, 1936).

Material

The species of *Rosellinia* under investigation was originally obtained by Horne and Nitimargi, in course of their investigation into the fungal population in the air of the apple orchard of the East Malling Experimental Station (England) from whom it was obtained by the present author*. When first isolated in standard medium from the air, *Rosellinia* was associated with a bacterium. In order to get a culture free from the bacterium, the fungus was grown in simple agar (Brown 1924). During the growth the fungal hypae outgrew the bacterium which remained restricted to the centre of the colony. Portions from these uncontaminated hyphae were sub-cultured. The cultures of *Rosellinia* used for the experiment were derived from a single hyphal tip of the bacteria-free culture.

Experimental

For the determination of the chemicals responsible for the inhibition of the development of perithecia in *Rosellinia* there were two lines of approach.

1. To start with the standard synthetic medium where perithecia *do not* develop and to arrive at a medium where perithecia do develop by the gradual *elimination* of constituent chemicals one after another and in combination.

2. To start with the agar medium in which perithecia are known to develop and to arrive at a medium where perithecia do not develop by the *addition* of constituent chemicals of standard medium singly and in combination.

The second method was adopted and the following media were employed. The proportions of the constituent chemicals in each medium correspond to that of the standard synthetic medium which are as follows:—Agar 1.5%, Asparagin 0.2%, Glucose 0.2%, $MgSO_4$ 0.075%, K_3PO_4 0.125%, Starch 1%.

A. Agar.

B. Agar+Asparagin.

C. Agar+K_3PO_4.

D. Agar+$MgSO_4$.

E. Agar+Glucose.

F. Agar+$MgSO_4$+K_3PO_4.

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*Author's thanks are due to Dr. A. S. Horne and the late N. M. Nitimargi for the culture.

G. Agar+Glucose+Asparagin.

H. Agar+$MgSO_4$+Asparagin.

I. Agar+K_3PO_4+Asparagin.

J. Agar+K_3PO_4+Asparagin+$MgSO_4$.

K. Agar+K_3PO_4+$MgSO_4$+Glucose.

L. Agar+K_3PO_4+$MgSO_4$+Starch.

M. Agar+K_3PO_4+$MgSO_4$+Glucose+Asparagin.

N. Agar+K_3PO_4+$MgSO_4$+Glucose+Starch.

O. Agar+K_3PO_4+$MgSO_4$+Glucose+Starch+Asparagin.

Plates in duplicates inoculated with the mycelium from the advancing regions of *Rosellinia* cultures, three days old, were placed at 20°C and examined periodically. The number of perithecia formed in young cultures was counted by putting ink dots on the bottom and the lid of the petridish against each perithecium, but for older cultures which had been allowed sufficient time to exhaust all possibilities of formation of fresh perithecia these were counted by picking perithecia out one after another by means of a needle. In all such counts only the perithecia which had formed dark peridium and were visible to the naked eye were taken into consideration. Incipient perithecia and those with hyaline peridium were not counted. The first sign of perithecia was evident about 72 hours after the inoculation but generally mature perithecia were not formed till after 5 days' growth. The experiments were repeated several times. While in each experiment several minor variations, such as the actual number of perithecia formed, were observed, they substantially confirmed the main result. The results obtained from a series of five experiments are given in tabular form (Table).

The positive (+) and negative (—) signs in the tables indicate respectively the presence and the absence of perithecia. The relative amounts of perithecia formed in different media and in different experiments are roughly denoted by the number of positive sign.

The table shows that asparagin, K_3PO_4, $MgSO_4$ and glucose severally have no inhibitory effect on the production of perithecia (media B, C, D, E). A slight inhibition is observed when two chemicals are added together, such as K_3PO_4+$MgSO_4$ (F), $MgSO_4$+asparagin (H) and glucose+asparagin (G). In the last two media G and H a change in the reaction of the fungus is observed. Perithecia are produced some of which are normal, but others with asci in which ascospores remain entirely hyaline and undifferentiated.

Very interesting result is obtained with medium I which consists of agar+aspargin+K_3PO_4. K_3PO_4 in combination with asparagin completely inhibits the production of perithecia. As will be seen

Table 1.

Symbol.	Medium.	Expt. I	Expt. II	Expt. III	Expt. IV	Expt. V.	Nature of Perithecia formed.
A.	Agar	++++	++++	++++	++++	++++	Mature.
B.	Agar + Asparagin	++++++	++++	++++	++++	++++	Mature.
C.	Agar + K_3PO_4	++++	++++	++++	++++	++++	Mature.
D.	Agar + $MgSO_4$	++++	++++	++++	++++	++++	Mature.
E.	Agar + Glucose	++++	++++	+++	++++	+++	Mature; Immature.
F.	Agar + $MgSO_4$ + K_3PO_4	+++	+++	++++	++++	++++	Mature.
G.	Agar + Glucose + Asparagin	+++	++++	++++	+++	++++	Mature; Immature.
H.	Agar + $MgSO_4$ + Asparagin	++++	++++	++++	++++	++++	Mature; Immature.

I.	Agar+K_3PO^4+Asparagin	—	—	—	Very few	—	Empty; Immature.
J.	Agar+K_3PO_4+Asparagin+$MgSO_4$ ..	A few	—	—	A few	A few	Immature.
K.	Agar+K_3PO_4+$MgSO_4$+Glucose ..	++	++	++	++	++	Immature; Mature.
L.	Agar+K_3PO_4+$MgSO_4$+Starch ..	++	+	+	++	+	Immature; Empty.
M.	Agar+K_3PO_4+$MgSO^4$+Glucose+ Asparagin.	—	—	—	A few	—	Immature; Empty.
N.	Agar+K_3PO_4+$MgSO_4$+Glucose +Starch.	++	++	+	++	++	Immature; Empty.
O.	Agar+K_3PO_4+$MgSO_4$+Glucose+ Asparagin+Starch.	—	—	—	—	—	No perithecia.

from the table, out of the five experiments made there is complete absence of perithecia in four and in one case (expt. IV) only five perithecia are formed; these too are empty without any asci. The result is peculiar since neither K_3PO_4 nor asparagin individually has any inhibitory influence on the production of perithecia. The effect cannot be due to the change in PH since there is no relation between the PH of the media employed and the production of perithecia and further no corroborative evidence was obtained while *Rosellinia* was grown in acid and alkali series.

The addition of $MgSO_4$ to agar+K_3PO_4+asparagin (medium J) has the effect of counteracting the combined inhibitory influence of K_3PO_4 and asparagin to a slight extent. In two experiments (II and III) no perithecia developed. In experiments (I, IV and V) a number of immature perithecia were produced. Glucose greatly counteracts the effect of $MgSO_4$ as will be seen from the result in the in all experiments but one perithecia failed to develop, even where medium (M), agar+K_3PO_4+$MgSO_4$+asparagin+glucose. Here they did, the number proved to be very few and all of them immature. The inhibition was further enhanced by the addition of starch (medium O which is the standard medium proper).

The following table will make the point clear :—

Table II

Symbol.	Medium.	Expt. I.	Expt. II.	Expt. III.	Expt. IV.	Expt. V.
B.	Agar+Asparagin ..	++++++	++++	++++	++++	++++
C.	Agar+K_3PO_4 ..	++++	++++	++++	++++	++++
I.	Agar+K_3PO_4+ Asparagin ..	—	—	—	Very few	—
J.	Agar+K_3PO_4+ Asparagin+ $MgSO_4$ ..	A few	—	—	A few	A few
M.	Agar+K_3PO_4+ Asparagin+Mg SO_4+Glucose .	—	—	—	A few	—
O.	Agar+K_3PO_4+ Asparagin+Mg SO_4+Glucose+ Starch ..	—	—	—	—	—

A further scrutiny of the results shows that agar+K_3PO_4 (C), agar+$MgSO_4$ (D) and agar+K_3PO_4+$MgSO_4$ (F) have no inhibitory influence on the production of perithecia but with the addition of asparagin (J) definite inhibition occurs.

Table III

Symbol.	Medium.	Expt. I	Expt. II	Expt. III	Expt. IV	Expt. V
C.	Agar+K_3PO_4 ..	++++	++++	++++	++++	++++
D.	Agar+$MgSO_4$ ..	++++	++++	++++	++++	++++
F.	Agar+K_3PO_4+ $MgSO_4$ ..	++++	++++	++++	++++	++++
J.	Agar+K_3PO_4+ $MgSO_4$+Asparagin.	A few	—	—	A few	A few

Since asparagin with $MgSO_4$ has no inhibitory effect (medium H) the result is due to the combined effect of asparagin and K_3PO_4. Thus corroborating the result obtained with the medium I.

Effect of Glucose.—As none of the constituent chemicals of the standard medium was found to exert an inhibitory influence on the production of perithecia when supplied in proportion given for the standard medium, experiments were carried out in which the concentration of individual chemicals was varied. The full results of the investigation will be given in a later publication. Some very interesting results obtained with glucose will be considered here.

Rosellinia was grown in the following concentrations of glucose 0.025%, 0.05%, 0.1%, 0.2%, 0.3%, 0.4%, 0.5%, 0.75%, 1%, 2%, 3% and 4% and incubated at 20°C. The plates were examined periodically for the perithecia and the rate of growth noted. The perithecia were counted in the same way as described before. While considering the perithecial number it should be borne in mind that the actual number of perithecia formed is variable and differs from experiment to experiment although carried out in identical conditions. The perithecial number of two different experiments are therefore not strictly comparable. The results of the investigation are given in Table IV.

It will be evident from Table IV that with the increase in the glucose concentration upto 4% there is hardly any change in the rate of growth of the fungus, on the other hand it indicates a slight increase at 0.5% glucose and over if at all. Perithecia are formed in all concentrations of 0.025, 0.05, 0.075, 0.1, 0.2 and 0.3 per cent glucose. The first visible sign of mature perithecia are found on the sixth day in all concentrations upto 0.2%. Perithecia in these media are mostly fertile. The number of immature perithecia slightly increases at 0.2% and 0.3% glucose. At 0.3% glucose the first indication of perithecia appear on the tenth day.

Table IV

Showing the Effect of Glucose on the Production of Perithecia.

Glucose in gram per 100 cc.	Diam. of Culture (3 days growth)	No. of Perithecia.	Nature of Perithecia.
0·00	60	2,132	Mature.
0·025	66	1,976	Mature.
0·05	64	2,310	Mature.
0·075	68	2,213	Mature.
0·1	68	2,520	Mature.
0·2	70	2,075	Mature (mostly)
0·3	68	1,890	,, ,,
0·4	68	—	—
0·5	76	—	—
0·75	72	—	—
1·0	70	—	—
2·0	70	—	—
3·0	68	—	—
4·0	72	—	—

The most interesting feature of the result obtained is the total inhibition of the perithecia in media with 0.4% glucose and over. In all concentrations higher than 0.3% no perithecia developed although the cultures were kept for over 45 days. The experiment was repeated several times and on each occasion corroborative results were obtained.

0.4% glucose, the inhibition point of perithecia formation is not at all high. In fact, it is below the normal proportion given for common synthetic medium. The fungus so far as the production of perithecia is concerned is distinctly averse to this form of carbohydrate.

Effect of Potassium phosphate (K_3PO_4).—Potassium phosphate exerts an inhibitory influence on the production of perithecia at a concentration higher than that prescribed for the standard medium as will be evident from Table V.

Table V

Showing the Effect of $K_3 PO_4$ on the Production of Perithecia.

$K_3 PO_4$ in gms. per 100 cc.	Diameter of culture 4 days growth.	Number of Perithecia	First visible sign of Perithecia in days after inoculation.	Nature of Perithecia.
0.00	80	792	7	Mature.
0.01	70	935	10	Mature.
0.03	80	707	10	Mature.
0.10	84	639	9	Mature.
0.3	76	1128	7	Mature & Immature (small).
0.6	28	..	..	..
0.9	10	..	..	..
2.5	..	..	..	..
7.5	..	..	..	..

Table V shows that the number of perithecia formed is practically the same for all concentrations upto 0.10%. When the amount is increased to 0.3% a larger number of perithecia appear but these are considerably smaller in size. A 0.6% the growth rate of the fungus drops considerably and at the same time the formation of perithecia is completely inhibited. At a still higher concentration (0.9%) rate of growth is further lowered till at 2.5% K_3PO_4 there is no growth at all.

The addition of K_3PO_4 to the basic agar medium in small quantity such as 0.01, 0.03 and 1.0 per cent has the effect of delaying the appearance of perithecia by about three days. At a higher concentration of 0.3 per cent the time required is the same as in plain agar (7 days).

Discussion

Several important points have emerged from the study of the inhibitory effect of chemicals on the production of perithecia in the species of *Rosellinia* under investigation. When used in concentration prescribed for the standard synthetic medium none of the chemicals, asparagin, magnesium sulphate, potassium phosphate

(K_3PO_4) or potato starch has severally any retarding effect. This is evident from the fact that perithecia are equally numerous in plain agar and in agar medium to which each of these constituents has been added separately. Asthana and Hawker (1936) while working with *Melanospora destruens* found that KH_2PO_4 and KNO_3 are essential for the production of perithecia; absence of any of these constituents from the basic medium completely inhibits the perithecial development. The result is thus different from that obtained with *Rosellinia* since in this fungus perithecia are formed in plain agar.

The inhibitory effect of the standard medium on the production of perithecia in *Rosellinia* has been traced to the combined action of potassium phosphate (K_3PO_4) and asparagin. The fact is very interesting since separately each of these is unable to produce any effect on the production of fruit bodies by *Rosellinia.* Whenever K_3PO_4 and asparagin are together present in a medium perithecia fail to develop. The intense inhibitory effect of the two chemicals, however, is slightly modified by the addition of magnesium sulphate. A few perithecia are then found to be produced almost in all cases. With the addition of glucose and starch the adverse effect on the production of perithecia becomes accentuated.

The perithecia formed in different media are by no means uniform. They show various degrees of maturity according to the nature of the medium employed. In media agar; agar+asparagin; agar+potassium phosphate; agar+magnesium sulphate and agar+$MgSO_4$+glucose, the perithecia formed are mature and abundant. But in media agar+glucose; agar+glucose+asparagin and as the number of chemicals added to simple agar becomes more and more, the number of immature and empty perithecia predominate. In fact in such media very few mature perithecia can be obtained.

Yonemoto and Kato (1931) working on the factors influencing the perithecial formation of *Aspergillus glaucus* Link. found that dextrose, glucose, maltose, sucrose, levulose, glycerine and galactose all promote the formation of perithecia, whereas inulin, glycogen, raffinose and corn-starch have no noticeable effect. As the results are taken from an abstract (the original paper not being available to the author), the actual concentrations of the chemicals employed are not known. It seems, however, that in the case of *Aspergillus glaucus* most of the ordinary carbohydrates exert a favourable effect.

Asthana and Hawker (1936) has shown that in the absence of glucose the fruiting is hastened by four days in *Melanospora destruens* although there is a retardation in the vegetative growth. The optimum glucose concentration for the production of perithecia in *M. destruens* is 0.1%, but the fungus fails to maintain the advantage gained at the initial stages since in older standard medium cultures in all concentrations of glucose employed (0.0–0.5%) the perithecial frequency is found to be the same. It has been recognized by Asthana and Hawker that the stimulatory effect in sporulation is largely due to reduction in glucose concentration.

The inhibitory effect of glucose on the production of perithecia in the species of *Rosellinia* under investigation has been clearly brought out in this paper. The effect is very slight when used in concentration given for the standard medium (0.2%); only a number of perithecia fail to mature. With the increase in the concentration of glucose, the infertile immature perithecia increase in number, ultimately when the concentration is raised to 0.4% perithecia fail to develop entirely. The highest concentration of glucose at which perithecia have appeared is 0.3%. The dimensions of the perithecia also showed some difference with the glucose concentration, but no change was found in the dimensions of the asci and ascospores. Upto the concentration of 0.1% the dimensions of perithecia formed were normal as in plain agar, but at higher concentrations these proved to be considerably smaller.

Unlike the result obtained by Asthana and Hawker there was hardly any effect of glucose on the vegetative growth of *Rosellinia* although the amount of glucose used was as high as 4%. There is no relation between the vegetative growth of the fungus and the production of perithecia. At the concentrations 0.4, 0.5, 0.75, 1.0, 2.0, 3.0 and 4.0 per cent glucose the vegetative growth was as vigorous as in the lower concentrations employed but in no case was there any perithecia formed. The time required for the production of perithecia varied with the glucose concentration. In plain agar medium the first visible sign appeared on the 6th day. With the addition of glucose upto 0.075% there was no material change in the length of time required for the appearance of perithecia. Beyond 0.075%, however, and upto the concentration of 0.3% perithecia took longer to develop, the time varying between twelve and fifteen days according to the concentration.

The amount of glucose that inhibits the formation of perithecia is quite low (0.4%). The inhibitory effect therefore can hardly be due to the change in the osmotic pressure of the medium caused by the addition of the glucose. The inhibition is not due to the change in the pH either, since no correlation could be obtained between the pH of the media employed and the production of perithecia.

Potassium phosphate (K_3PO_4) has also been found to inhibit the formation of perithecia at a comparatively low concentration of 0.6%. This concentration, however, greatly exceeds that prescribed for the standard synthetic media commonly employed.

Potassium phosphate is also found to delay the appearance of perithecia at the lower concentrations employed. For example, while perithecia appear after six days in plain agar, they take about ten days to appear in media having 0.01, 0.03 and 0.1 per cent K_3PO_4. At the highest concentration of K_3PO_4 where perithecia are known to develop, the time required is again seven days.

Summary

As a species of *Rosellinia* produced numerous perithecia in plain agar and none was formed in the standard synthetic medium, the various chemicals constituting the standard medium were tested singly and in combination for their possible inhibitory effect. The main results are as follows:—

In proportion given for the standard medium, glucose, asparagin, magnesium sulphate, potassium phosphate (K_3PO_4) severally has no inhibitory effect.

Asparagin and potassium phosphate exert a strong inhibitory effect when used together. The effect is accentuated by the addition of glucose and starch and lessened by the addition of $MgSO_4$.

Glucose completely inhibits the formation of perithecia at concentrations 0.4% and beyond although the growth rate of the fungus remains unaffected.

Potassium phosphate (K_3PO_4) inhibits the formation of perithecia at about 0.6% concentration, an amount considerably higher than that employed in standard synthetic media.

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REVIEW

Floral Morphology: a new outlook, with special reference to the interpretation of the gynæceum. By E. R. SAUNDERS. Vol. I. Cambridge: W. Heffer & Sons, Ltd., 1937. 3s. 6d. net.

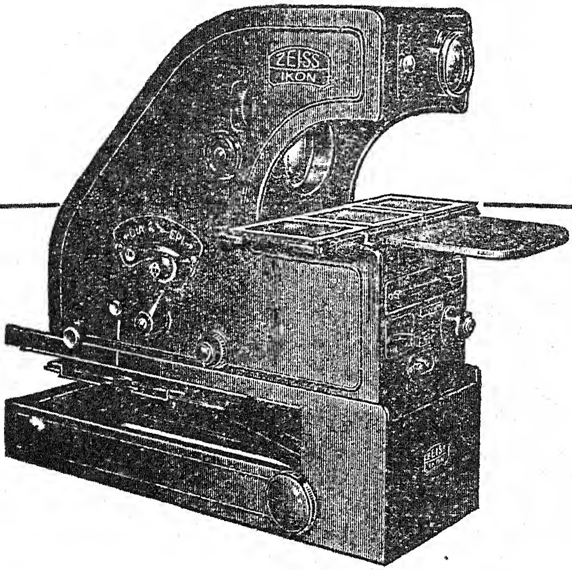
The numerous papers from the pen of Miss E. R. Saunders since 1923 have made us all familiar with the theory of Carpel Polymorphism, though what it exactly implies few botanists have understood. She has fought for it with such confidence and vigour as to receive the sympathies of some, but all who have critically examined her views had finally to reject them. Some have even called them fantastic.

Undeterred, however, by any criticism, she has continued to fight. In the present volume she has prepared a brief statement of the substance of her voluminous work published during the last 13 years. It is divided into four parts. The first part is introductory and here the author gives a general account of her views on the construction of the angiospermous flower. In the following three parts she has outlined on this basis the floral structure of 32 dicotyledonous and 7 monocotyledonous families, particularly choosing those types which afford the clearest evidence in support of the new interpretation.

A summary of her own work by the author of Carpel Polymorphism at this stage is most welcome, but a note of warning needs to be uttered about the purpose for which it is written. The author says that the book has been designed especially to serve as a guide to the study of the types in the class. This is rather objectionable. Many others also will emphasize the necessity of supplementing the observations on the external form of the flowers by a study of their vascular anatomy in the higher classes, but that such a study should be based on Carpel Polymorphism every other worker on floral morphology would unhesitatingly deny. Such a step will be harmful for the students. Even without Carpel Polymorphism the study of gynæceal morphology is often confusing. The introduction of Carpel Polymorphism in the elementary or undergraduate classes would create greater confusion.

The book is neatly got up and its low price should make it available to many. It is nearly free from any errors. The only one I have observed is on p. 97, where in the list of the families dealt with in part IV Juncaceæ should be Cyperaceæ.

A. C. JOSHI.



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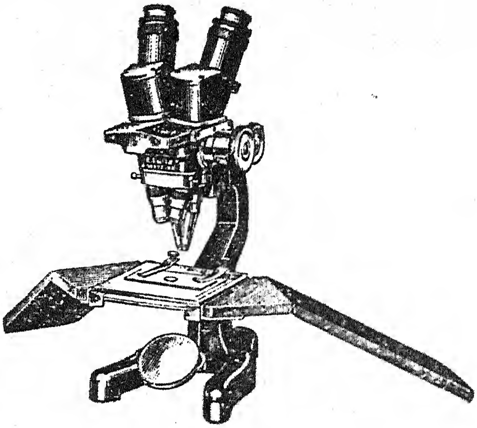

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